

Final Report

Investigation Into Service Quality Provided By Public Service Company Of New Hampshire Within The Town of Bedford, New Hampshire



For:
**New Hampshire
Public Utilities Commission
Docket No. DE 03-113**

Prepared by
Dufresne-Henry

August 31, 2004



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CERTIFICATION PAGE
BEDFORD UTILITY STUDY

FINAL REPORT

For

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CERTIFICATION

I hereby certify that this Report was prepared by me or under my direct supervision and that I am a duly licensed Professional Engineer under the laws of the State of New Hampshire

Date: August 31, 2004

Reg. No. P.E. # 3971

Signed: _____

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EXECUTIVE SUMMARY

INTRODUCTION

Dufresne-Henry conducted this study and analysis as a follow-up to a report prepared by Vantage Consulting, Inc. in August 2003. Our approach was to collect and review existing documentation, conduct independent familiarization visits of the PSNH power distribution system, monitor voltage conditions on the utility system and within the electrical systems of two public buildings and prepare this report of our findings.

A number of Bedford residents have a healthy interest in the quality of the electric service provided by PSNH and their concerns are certainly valid, especially where some issues have remained active for a considerable time. PSNH appears responsive and has upgraded their facilities to remedy a number of complaints.

We selected five distribution feeders, out of approximately 20, for our review since they cover approximately 70 percent of the PSNH customers in Bedford.

PSNH maintains the customer voltage levels within NHPUC requirements, based on our monitoring.

Voltage measurements within a customer's electrical system indicated short term voltage sags caused by the operation of different types of customer equipment.

We propose a Power Quality Team approach to as a method to successfully solve the ongoing issues that have resisted resolution to date.

SUMMARY OF FINDINGS

The following listing is a summary of our findings which are developed and explained in the indicated Sections.

SECTION 4 PSNH SYSTEM AND MAINTENANCE ACTIVITIES IN BEDFORD

- F1 PSNH responds to voltage complaints and, when voltage problems are confirmed, the most frequent action is to repair or upgrade their facilities.
- F2 Approximately 40% of voltage complaints require corrective action of some type.
- F3 PSNH conducts an ongoing thermovision testing program to locate and correct potential problems on the mainline distribution circuits twice yearly. Only three problems were noted on the circuits studied in Bedford.
- F4 PSNH has scheduled over 100 miles of tree trimming in Bedford during 2004.
- F5 PSNH tested the ground resistance at 49 locations on the 3W2 distribution circuit and the results were comparable with the previous test four years earlier. No unusual readings were reported.
- F6 PSNH maintains a documented record on customer complaints and their responses; however the data collection process does not appear to identify the cause of some power quality problems experienced by customers.

SECTION 7 UTILITY MONITORING RESULTS

- F7 The voltage on the 3W2 circuit remained within NHPUC limits during the monitoring period.
- F8 The voltage on the 322X10 circuit remained within NHPUC limits during the monitoring period.

SUMMARY OF RECOMMENDATIONS

The following listing is a summary of our recommendations which are developed and explained in the indicated Sections.

SECTION 4 PSNH SYSTEM AND MAINTENANCE ACTIVITIES IN BEDFORD

- R1 PSNH should take ground resistance readings on a periodic basis to verify grounding integrity on distribution circuits. Investigation and remediation should be taken at locations where the resistance values are significantly higher than the previous test.
- R2 PSNH should periodically review the questions used to obtain problem information from the customer and revise the questions to obtain specific data to better define power quality issues for corrective action.

SECTION 5 NHPUC VOLTAGE REQUIREMENTS AND UTILITY STANDARDS

- R3 The NHPUC should consider reviewing the voltage regulation criteria under Paragraph PUC 304.02 to determine if a modification to the present voltage limits would improve overall power quality.

SECTION 7 UTILITY MONITORING RESULTS

- R4 PSNH should investigate the cause of the ground current reading of 3.15 amps at Pole 842/25 at the Town Hall.

SECTION 9 REPORT SUMMARY AND RECOMMENDATIONS

- R5 Consider developing a Power Quality Team concept combining PSNH resources and licensed electricians to investigate situations that have resisted other attempts at resolution.

SECTION 1

PROJECT OVERVIEW

1.1 INTRODUCTION

The State of New Hampshire Public Utilities Commission (NHPUC) retained Dufresne-Henry (DH) to investigate and determine if safety and reliability problems exist in the Town of Bedford, New Hampshire under Commission Docket DE 03-113.

There have been ongoing power quality complaints from Bedford residents concerning the failure of electrically operated equipment and appliances over several years. The NHPUC ongoing inquiry seeks to determine if there are utility related problems and what corrective actions would be required.

The electric utility serving Bedford is the Public Service Company of New Hampshire (PSNH).

This report is intended to supplement the previous work of others and to investigate areas where we feel that additional research would be helpful in focusing on topics that may not have been fully explored in the past. Where possible, our goal is to pursue a process of elimination and develop direction for possible future action.

1.2 BACKGROUND

The NHPUC opened an inquiry to investigate complaints received from electric customers in the Town of Bedford in 2003, and retained Vantage Consulting, Inc. to determine the validity of the complaints. The Vantage Report is discussed in Section 3.

Public presentations to the Town of Bedford by PSNH have indicated a 45% growth rate in the town for the 10 years ending in 2003. The utility has a number of capital improvement projects to upgrade electrical distribution facilities in the town; however this does not seem to have solved the complaints. As the town continues to grow, there is a combination of new customers being added to the system and increasing electrical loads for existing customers at

the same time. This load growth has the potential to reveal new problems, or aggravate existing problems for some customers.

This report is intended to build on previous work and does not seek to duplicate those efforts. For example, we did not feel a need to interview the customers or PSNH staff again.

1.3 APPROACH

Dufresne-Henry commenced an independent evaluation on behalf of the NHPUC looking for new information to further define the situation, document conditions and seek possible solutions. This was accomplished through the following steps.

1.3.1 FAMILIARIZATION PHASE

- Attended a public work session conducted on March 17, 2004 by the NHPUC in Bedford and broadcast on a local cable channel. At this meeting, residents described their concerns and experiences in their own words and some also provided this information on forms provided by the Consumer Affairs Division. This became our baseline for understanding the customer concerns.
- Reviewed the Final Report, dated August 1, 2003, by Vantage Consulting, Inc.
- Reviewed the September 5, 2003 response to the Vantage Report filed by PSNH.
- Reviewed the various customer comments regarding the Vantage Report filed in response to the September 26, 2003 public comment deadline.
- Reviewed other materials filed with the Commission Docket DE 03-113, data responses and Bedford Power Survey information.
- Requested information from PSNH on various topics. Where referenced in this report, these responses are referenced within parentheses.

- Conducted field investigations of the Bedford distribution circuits to observe existing conditions, confirm existing data and familiarize ourselves with the distribution system configuration.

1.3.2 PRELIMINARY OBSERVATIONS FROM THE FAMILIARIZATION PHASE

- The customer concerns did not focus on sustained outages but rather flickering lights, surges, momentary power failures and loss of equipment. The causes of sustained outages will not provide the evidence necessary for this investigation.
- This investigation concentrates on serving the public through new initiatives, rather than duplicating past activities, and we pursued this direction with the concurrence of the NHPUC staff.
- We summarized existing information and to obtained new data in an attempt to define and identify the causes of customer dissatisfaction.
- Our goal was to provide a report that could enable a layperson to understand the system complexities and interrelationships among circuits, customers and power quality issues. We desired to provide clarity and understanding, rather than technical jargon, regarding our findings.

1.3.3 ANALYSIS PHASE

Our basic approach was to consolidate customer concerns by location, familiarize ourselves with the Bedford power system, conduct voltage testing and provide additional information on topics of customer concern. Specifically, we performed the following tasks:

- Obtained system information from PSNH, including distribution maps, recloser operational data, infrared survey forms, E1 forms, tree trimming schedules and other related data.
- Reviewed five years of data and documentation due to the longevity of some of the customer complaints.

- Developed an Electrical Distribution Circuit Map to show the relationship of the distribution circuits and roads.
- Developed a Customer Concerns Schedule to consolidate the complaints, concerns, timeframe and utility responses.
- Developed a 5 Year Recloser Activity Schedule to track the number of recloser operations on the circuits.
- Identified the locations of capacitor banks and regulators on the distribution circuits and provided details such as size and control methodology in the Capacitor Bank Schedule.
- Determined the utility's Tree Trimming Schedule for the Bedford distribution circuits.
- Identified two circuits for voltage monitoring and prepared a Monitoring Program to be conducted jointly with PSNH assistance.
- Prepared and submitted a Final Report to the New Hampshire Public Utility Commission.

1.4 SUMMARY

The overall issue is reliability and the maintenance of service voltage within NHPUC limits.

Those portions of the report discussing issues within the customer systems, and some short term voltage deviations, are not within the legal voltage constraints imposed on the utility by the NHPUC. These items may be significant with regard to the customer and are presented as additional information in an attempt to provide increased understanding and guidance toward ultimate resolution.

Acknowledgements

The assistance of the NHPUC staff is greatly appreciated, especially in providing documents and the allowing flexibility to adjust our scope and direction to follow the facts as they developed.

We found PSNH responsive to our information requests and at no time did they attempt to suggest conclusions or influence our efforts. Their cooperation and assistance in the installation of our monitoring equipment on their poles, and the switching of capacitors and regulators during the testing program, is particularly noteworthy.

We especially appreciate the input from the interested Bedford residents who related their concerns at the March 2004 NHPUC Work Session in Bedford and for their written input in various forms. This information was crucial to our understanding and served as the starting point for our efforts.

SECTION 2

CUSTOMER CONCERNS

2.1 EXPLANATION OF CUSTOMER CONCERNS SCHEDULE

Our initial orientation to the concerns and experiences of Bedford residents regarding power quality issues occurred at a NHPUC sponsored public work session on March 17, 2004 in Bedford. We followed up by obtaining copies of written comments that had previously been submitted on this topic to the NHPUC and received copies of a customer initiated power survey directly from a resident. We also requested information from PSNH.

The Customer Concerns Schedule, Figure 2.1A, is a single compilation of concerns based on correspondence received directly from Bedford residents or through the NHPUC or PSNH. This data covers a five-year period from January 1999 through December 2003 and includes information extracted from:

- PSNH quarterly reports for Voltage Complaints, E-1 forms.
- Power Quality Investigation Survey responses from Bedford residents.
- Miscellaneous e-mails, letters and correspondence from Bedford residents.
- Customer comment sheets from the 2003 Vantage Report.
- Customer comment forms from NHPUC Consumer Affairs Division.

One potential problem in this effort was the need to maintain customer confidentiality and at the same time locate and sort each reported concern on the related distribution circuit layouts. The NHPUC permitted us to assign an index number to each affected customer location. A single customer location may have one or more complaints, concerns or correspondence as noted by a repeated index number in the schedule.

There is some inconsistency in the data listed for each customer because the content and format of the various source documents varied. Where individual equipment failures were listed, an “X” was placed on the schedule or a number was used to indicate multiple failures of the same type of equipment. Additional information and comments, to the degree they were available, were added to further identify problem areas, provide individual customer observations and list the type of corrective actions taken to resolve the issue.

2.2 EXPLANATION OF ELECTRICAL DISTRIBUTION CIRCUIT MAP

This map, Figure 2.2A, combines the Town of Bedford street map with an overlay of the five major PSNH distribution circuits, showing the locations of capacitors banks, reclosers and voltage regulators. See Section 4.1 for additional information on these five feeders. (DH-01, Q-DH-001; DH-02, Q-DH-002)

Each customer concern location is represented by an index number inside a yellow diamond symbol. The locations are approximate and are not intended to identify any specific customer. The primary value of this map is the correlation of available information for further analysis.

This map provided insight into the interrelationships of reported concerns and guided the development of the voltage monitoring program for further data collection. Initial areas of interest include the 3W2 circuit, the 322X10 circuit and the far end of the 322X12 circuit. On the other hand, the 360X5 and 3W1 circuits appear to have fewer concerns, but this does not minimize the validity of the individual customer comments.

2.3 EXPLANATION OF SCHEDULES FOR ELECTRICAL DISTRIBUTION CIRCUIT MAP

Additional reference information related to the distribution feeders is contained on a separate sheet, Figure 2.3A, and serves to amplify some information on the map or provide a summary of available related information. Each schedule, and its purpose, is described below.

2.3.1 FIVE YEAR RECLOSER ACTIVITY SCHEDULE

Reclosers are protective devices which could be thought of as automatic circuit breakers in function. If an overcurrent condition is detected, the recloser will open the circuit and remove voltage from the downstream circuit. After a short time delay, the device will close again to restore power. If the overcurrent persists, it will repeat the open-close cycle. If the abnormal condition is cleared, the power will remain on; but if the fault remains, the device will lock open after a set number, generally 3 or 4, open-close operations. This is why the power may cycle on and off several times before a sustained outage occurs.

Each recloser is individually programmed to protect the downstream circuit. Several built-in counters track the number of operations to assist the line crews in diagnosing any circuit problem. The Five Year Recloser Activity Schedule summarizes the counter data in several categories to identify the number and causes of circuit problems. A brief description of each column follows:

- (A) - Total counts represents the total of all recloser operations and is the sum of the other counts. This number by itself is not necessarily significant and must be interpreted in context with the other counters.
- (B) - Test counts are the number of recloser operations manually conducted by the utility to test and maintain this equipment. Manual testing does not result in any customer service interruptions.
- (C) - Lockout operations are the number of operations related to sustained outages. If the recloser cycled three times before lockout, three operations would be recorded.
- 2003 Outages is a new column for the 2003 data only and represents the actual number of sustained outages isolated by the recloser. If the recloser cycled three times before lockout, then only one sustained outage would be recorded in this column.

- (D) - Net operations represents all remaining operations not included in the other counts. The momentary operations represent any outage of short duration, such as a tree branch contact caused by wind. Typically these conditions are self-correcting during on-off recloser cycling.
- (E) - Customers per operation is the number of customers who are served by the recloser and affected by its operation.
- (F) - Momentary interruptions is the number of momentary operations (D) multiplied by the number of customers affected (E). For the utility, this is a measure of the nuisance effects of momentary interruptions on customers.

Momentary interruptions are closely related to tree contact events, a combination of tree exposure and windy weather conditions. Regular tree trimming along the distribution circuits is essential to minimize the number of momentary interruptions. (DH-04, Q-DH-002; DH-07, Q-DH-002, Attachment 2)

2.3.2 TREE TRIMMING SCHEDULE

Because of the relationship between tree trimming on momentary recloser operations, this schedule indicates the last and next planned trimming dates along with the circuit length to be maintained. New Hampshire law allows individual landowners to withhold permission to trim trees on their property and the impact of this law is unknown as PSNH did not maintain historical records of property owner denials in response to tree trimming permission requests. (DH-05, Q-DH-001)

Tree trimming is discussed further in Section 4.

2.3.3 CAPACITOR BANK SCHEDULE

Capacitors are passive components installed on the distribution system to increase the overall power factor and reduce reactive losses caused by inductive loads such as transformers and motor loads. Distribution system efficiency is improved and the voltage level is improved by using capacitors to reduce the total current and related line losses. Some capacitors are

permanently connected and others are switched under time clock, voltage or temperature, depending on the design strategy. The locations are shown on the Electrical Distribution Circuit Map. (DH-07, Q-DH-002, Attachment 1)

2.3.4 CIRCUIT CONDUCTOR SCHEDULE

The distribution circuit conductors vary in size, based on the required ampacity and number of phases required. Most overhead conductors are bare ACSR (aluminum conductor, steel reinforced) except for some locations where spacer cable construction uses insulated wire or in limited areas where tree wire is used. (DH-01, Q-DH-001; DH-04, Q-DH-004)

2.3.5 CIRCUIT UPGRADE / TRANSFER SCHEDULE

PSNH has made system improvements and transferred portions of the system from one circuit to another. These changes are shown on the map and detailed in the schedule. (DH-04, Q-DH-001)

2.3.6 PSNH MONITORING LOCATIONS SCHEDULE

PSNH has an ongoing monitoring program in place and this schedule represents the location and type of meters reported in operation as of May 2004. These locations were selected by the utility and are included for reference only.

The metering program conducted as part of this report, is a totally separate and unrelated effort.

2.3.7 VOLTAGE REGULATORS

Voltage regulators are active devices that function to measure and adjust the voltage of the line. When line loads increase, the voltage is automatically increased to compensate for losses and then decrease the voltage as the loads decrease. Their function is to maintain a fairly constant line voltage despite varying customer loads.

Approximate locations of these devices are shown on the Electrical Distribution Circuit Map, but not otherwise scheduled. (DH-04, Q-DH-003)

2.4 DISTRIBUTION VOLTAGES

The primary distribution feeders are a 4-wire wye configuration that supplies line-to-line voltage at the nominal line-to-line voltage rating which is 1.73 times the line-to-neutral voltage. Thus the nominal 34.5 kV three phase circuit also provides 19.9 kV from line-to-neutral for single phase taps. The voltage is correctly listed as 34.5 / 19.9 kV, three phase, 4 wire. Similarly, the 12.47 / 7.2 kV, three phase, 4 wire designation applies to the lower voltage.

These voltages are indicated on the map to clarify the numerous locations where transformers on the distribution circuits are used to step the voltage either up or down between the two voltages. This has been done where portions of 12.47 kV circuits have been reconfigured and connected to the 34.5 kV system. There are also underground systems constructed for 34.5 kV operation that are presently fed from the 12.47 kV system.

SECTION 3

COMMENTARY ON THE VANTAGE CONSULTING REPORT

3.1 GENERAL OVERVIEW

The Vantage Report concisely describes the PSNH power distribution system in Bedford and the utility's approach to respond to trouble calls relative to power quality issues. It featured a site visitation and interview process with customers to gather information. They investigated reports of motor burnouts, short incandescent lamp life, appliance and electronic equipment failures, along with complaints of momentary power outages that required frequent clock resetting.

We found the Vantage Report to be understandable and well written, as well as technically correct in presentation. Given this level of agreement, we did not wish to duplicate the essence of their report and instead sought to expand the analysis and discussion into additional areas in an attempt to provide additional clarity and focus.

3.2 STRENGTHS

Vantage interviewed a cross section of utility customers in their homes and conducted limited investigation and voltage monitoring for one to two hours at each location. In one case, the voltage monitoring extended for five days. We reviewed the individual interview report sheets as part of our evaluation.

An additional 25 interviews were conducted with PSNH staff directly involved with management, operations, maintenance, protection, system design, tree trimming and vegetation management. Vantage also reviewed trouble reports, grounding records and other related information.

We found the discussion of equipment failures to be factual from an engineering perspective especially that an electrically powered device could fail because of a mechanical cause. This observation indicates the possibility of misdiagnosis in the case of some equipment failures.

One of the major conclusions was the lack of a common terminology for customers to describe problems in such a way that PSNH and others would have a consistent basis on which to document and ultimately identify any needed maintenance work.

The recommendation regarding tracking of tree trimming denials could help in determining the impact on momentary outages and perhaps provide some direction for future improvement.

The individual findings and recommendations are clear and to the point.

The recommendations concerning the establishment of a periodic ground resistance monitoring program and the installation of additional squirrel guards on the system are steps that could assist in improving the overall system reliability.

3.3 WEAKNESSES

The relatively short voltage monitoring periods did not provide the opportunity to identify any abnormalities that longer term voltage monitoring might discover.

We did not find any relationship between the problems noted by the customers and the specific distribution feeder and primary voltage level. Essentially, the power system was treated as a single entity without further investigation to determine if the problems were related to a specific circuit or primary voltage level.

We found the equipment failure discussion to be factual from an engineering perspective; however it was too general to assist individual customer efforts to diagnose specific failures. An example of the limited discussion is the lack of what lamp life ratings actually indicate.

We interpreted the report to indicate that most failures are directly linked to customer equipment. There is little information regarding the adequacy of the customer service equipment or utility service size or length. In our opinion, the root cause of each reported failure may lie with the utility, the customer or a combination somewhere in between.

Grounding issues were not discussed in any detail. The configuration of the typical customer service connection could affect power quality, yet this aspect seems to have been omitted.

There are other potential causes of equipment failures, beyond those listed in the Vantage Report. For example, well pumps, according to the Franklin Electric submersible pump application manual, can fail for other reasons:

- “Short-cycling,” a rapid on-off condition that could be caused by a waterlogged pressure tank or defective pressure switch, could reduce motor life by damaging the shaft spline, bearings and overheating the motor.
- Exceeding the maximum number of starts permitted in a 24 hour period. The manual lists a daily maximum of 300 starts for up to a 3/4 HP motor and 100 starts for a motor in the 1 to 5.5 HP range.
- A minimum one minute run time is recommended to dissipate the heat build up from the starting current inrush.
- Surge (lightning) arresters, to be effective on submersible motor circuits, should be grounded by a metallic connection all the way to the water level.

3.3 ITEMS CARRIED INTO THE DUFRESNE-HENRY REPORT

We considered some items from the Vantage Report for further study and included the following topics for exploration in our Dufresne-Henry report:

The Dufresne-Henry voltage monitoring program was scheduled to collect data for about a week at each location for evaluation.

Each reported customer concern was identified as to the specific issue and the general location of each was graphically depicted on a map to depict the extent of these concerns.

A commentary on grounding theory and practice was included to help provide a common basis for further discussion about utility and customer electrical systems.

A commentary was included to clarify the meaning of incandescent lamp life ratings

SECTION 4

PSNH SYSTEM AND MAINTENANCE ACTIVITIES IN BEDFORD

4.1 SYSTEM DESCRIPTION

4.1.1 DISTRIBUTION FEEDER ARRANGEMENT

Bedford is somewhat unusual with approximately 20 feeder circuits serving the town; all operating at 34.5 kV, except for two that operate at 12.47 kV. A large portion of the town is served by five circuits and the remaining feeders generally supply smaller areas or are portions of feeders originating in the surrounding towns. Most of the circuits are supplied by the 321 and 322 transmission lines operating at 34.5 kV. There were approximately 7,163 residential and 1,303 commercial customers according to PSNH 2003 data.

In the late 1960's, PSNH became one of the first utilities to use 34.5 kV distribution systems and they have considerably more experience with operation and maintenance of these systems than most other utilities.

The utility plans for load growth on a regional basis and does not forecast loads by individual distribution feeder. The Manchester area 2002/2003 winter peak load was 278.4 MW and winter load growth is forecast at 1.75% annually. The two recent summer peak loads were 323.3 MW in 2002 and 318.5 MW in 2003. Summer load growth is forecast at 3.75% annually. (DH-01, Q-DH-004)

The feeder number scheme is based on the source line number. For example, the 322 transmission line, supplies feeders 322X10 and 322X12; line 360 supplies 360X5; and other lines follow this same convention.

The Meetinghouse Road substation is normally fed from the 322 line and has the capability to operate from the 321 line in an emergency. This substation uses two separate transformers, one for the 3W1 and the second for the 3W2 outgoing feeders which operate at 12.47 kV. Each transformer has a base rating of 3,750 kVA, and forced air cooling increases

this rating to about 4,700 kVA. Integral load tap changers function as built-in voltage regulators for the outgoing circuits. (DH-04, Q-DH-004)

4.1.2 FEEDERS INVESTIGATED

Most of the town is served by the 322X10, 322X12 and 360X5 feeders operating at 34.5 kV and the 3W1 and 3W2 feeders operating at 12.47 kV. These five feeders have about 5,748 customers, about 70% of the Bedford total, and are the primary focus of our interest and study.

Each feeder may have one or more reclosers, capacitor banks or voltage regulators to improve the stability and reliability of the system and the locations of these devices are located on the Electrical Distribution Circuit Map.

4.1.2.1 Circuit 322X10

This circuit is tapped from the 322 line at the Donald Street and Cote Lane intersection and generally supplies the north central portion of the town. While operating at 34.5 kV, there are single phase step-down transformers feeding taps into several residential developments at 7.2 kV. Approximately 931 customers are on this circuit.

4.1.2.2 Circuit 322X12

This circuit is tapped from the 322 line where it crosses Route 101 and is protected by a recloser at the tap location. The circuit extends southwest and generally supplies the southwest portion of the town. While operating at 34.5 kV, there are single phase step-down transformers feeding taps into several residential developments at 7.2 kV. Approximately 1596 customers are on this circuit.

4.1.2.3 Circuit 360X5

This circuit is tapped from the 360 line in New Boston and is protected by a recloser at the tap. The circuit extends to the east and generally supplies the northwest portion of the town.

While operating at 34.5 kV, there are single phase step-down transformers feeding taps into several residential developments at 7.2 kV. Approximately 544 customers are on this circuit.

4.1.2.4 Circuit 3W1

This circuit originates at the Meetinghouse Road substation and extends southerly to supply the southeast portion of the town. Approximately 1235 customers are on this circuit, which had a 2003 peak summer load of 5.1 MVA. (DH-01, Q-DH-004)

4.1.2.5 Circuit 3W2

This circuit originates at the Meetinghouse Road substation and extends westerly across town to supply the central and western portions of the town. It also supplies an area to the south along Liberty Hill Road between the 3W1 and 322X12 areas. Approximately 1442 customers are on this circuit, which had a 2003 peak summer load of 4.8 MVA. (DH-01, Q-DH-004)



PSNH, in its presentation at the March 10, 2004 Bedford Town Council meeting stated that this circuit “has about 23 grounds per mile.”

4.2 MAINTENANCE ACTIVITIES

The electrical distribution system is similar to any other machine and requires ongoing maintenance. We maintain our cars on a routine basis by checking fluids, changing the oil, checking tire pressure and waxing the finish. When a serious problem occurs, we call a mechanic to fix it.

Similarly, PSNH has a number of ongoing active programs to diagnose and remedy potential problems before customer service is interrupted. In addition, they respond to customer power failures due to all sorts of causes. The following are some of the ongoing utility maintenance activities investigated during this study.

4.2.1 E-1 FORM RESPONSES

We reviewed five years of E-1 forms for Bedford to determine the types of response to customer voltage complaints by PSNH. These records indicate that some type of corrective action or system upgrade was made at those locations where voltage problems were confirmed. In some cases, the voltage recording data was found to be within NHPUC limits and no further action was required. (DH-05, DH-Q-006; DH-05, Q-DH-007)

Approximately 60 percent of voltage tests were determined to be within the NHPUC voltage limits and no further action was required. In some cases, repeated complaints resulted in additional testing at the same customer locations. Where problems were found, the most common resolution was to upgrade the transformer size and service conductors to improve voltage regulation and eliminate lamp flicker complaints. In one case, the transformer was relocated to shorten a service that was over 400 feet long.

The following table summarizes our findings of the E-1 forms provided by PSNH.

TABLE 4.2.1
E-1 FORMS SUMMARY

<u>TYPE OF RESPONSE</u>	<u>1999</u>	<u>2000</u>	<u>2001</u>	<u>2002</u>	<u>2003</u>	<u>TOTALS</u>
No Action Required, Within NHPUC Limits	10	-	9	6	9	34
Upgrade Facilities, Transformer or Service	5	1	3	3	3	15
Tighten Connections or Other Service Maintenance	-	-	2	1	1	4
Tree Trimming	-	-	-	1	-	1
Modifications to Primary Distribution Circuit	2	-	1	-	-	3
TOTAL	17	1	15	11	13	57

F1 PSNH responds to voltage complaints and, when voltage problems are confirmed, the most frequent action is to repair or upgrade their facilities.

F2 Approximately 40% of voltage complaints require corrective action of some type.

4.2.2 INFRA-RED/THERMOVISION TESTING

PSNH has a thermovision testing program for mainline distribution circuits and substations to locate and correct potential problems. For example, the winter 2004 testing was performed on the 3W1, 3W2, 322X10 and 322X12 mainline circuits in Bedford. An infra-red sensitive camera is used to record the relative temperature differences of equipment and devices on poles or in substations. For example, a loose terminal connection will be warmer than the attached cables and will show as a white image against a darker background. At the same time, the exact temperature of the equipment and its surroundings can be determined. This process provides an efficient visual method to identify specific problems and initiate an Engineering Work Request to correct the problem before a failure occurs.

This testing is scheduled twice a year, but reports were not necessarily available. Table 4.2.2 lists the thermovision reports reviewed and indicates that from a total of 48 problems found, only three were on the 5 major circuits in Bedford. Each of the problems was repaired and documented on the PSNH Engineering Work Requests. (DH-05, Q-DH-004; DH-06, Q-DH-002)

TABLE 4.2.2
THERMOVISION REPORTS

<u>REPORT DATE</u>	<u>TOTAL PROBLEMS</u>	<u>PROBLEMS IDENTIFIED IN BEDFORD</u>
Summer 1999	3	None
Summer 2000	11	None
Summer 2001	4	None
Summer 2002	3	None
Winter 2003	3	None
Winter 2003	6	3W2 – Recloser Line Tap at Pole 842/39 321 – Switch Connection Outside Meetinghouse Rd. S/S
Summer 2003	4	3W1 – Splice at Pole 9/67
Winter 2004	14	None

F3 PSNH conducts an ongoing thermovision testing program to locate and correct potential problems on the mainline distribution circuits twice yearly. Only three problems were noted on the circuits studied in Bedford.

4.2.3 TREE TRIMMING PROGRAM

PSNH performs scheduled tree trimming as part of their normal distribution circuit maintenance program. Tree trimming is the most effective way to minimize momentary power interruptions and the utility has scheduled a major effort in Bedford this year. Table 4.2.3 summarizes the last trimming and the next scheduled trimming for each of the five major circuits investigated in this report. Additional Bedford circuits scheduled for trimming are listed to demonstrate the overall extent of the trimming program in Bedford. (DH-07, Q-DH-002)

TABLE 4.2.3
TREE TRIMMING SCHEDULE

CIRCUIT NUMBER	TOTAL CIRCUIT LENGTH IN MILES	LAST TRIMMING CYCLE	TOTAL MILES TRIMMED LAST CYCLE	NEXT TRIMMING SCHEDULED	TOTAL MILES SCHEDULED FOR TRIMMING
3W1	28.05	1999	27.46	2004	28.05
3W2	52.05	1998	51.93	2004	52.05
322X10	11.94	2000	11.87	2004	11.94
322X12	85.53	2002	85.53	2008	85.93
360X5	14.10	2002	14.10	2008	14.10
Additional Circuits					
12X6	2.28	2000	2.28	2004	2.28
360X	5.6	2003	5.62	2007	5.62
323X5	48.4	2001	48.04	2006	48.4
321X1	4.09	2000	4.09	2004	4.09
321X10	3.5	2000	3.5	2004	3.5

F4 PSNH has scheduled over 100 miles of tree trimming in Bedford during 2004.

4.2.4 GROUND TESTING

The primary distribution system has a multi-grounded neutral configuration. PSNH, in its presentation at the March 10, 2004 Bedford Town Council meeting stated that



“Bedford’s electrical system has a minimum of 14 grounds per mile, on average” and that “a minimum of four grounds per mile is required for multiple grounded systems.”

Refer to Appendix A for further information on grounding requirements.

The Vantage Report found that there had been no ground resistance testing at the Meetinghouse Road substation since it was constructed. Testing, conducted as part of Vantage Report, found that the substation ground resistance was acceptable and measured less than one ohm. It recommended repetitive mid-winter testing on a 3 to 5 year schedule at the substation.

PSNH performed ground resistance tests on the 3W2 circuit in January 2004 from the substation west along Meetinghouse and North Amherst Roads to the regulators on pole 842/101 beyond West Drive, approximately 4 to 5 miles from the substation. A total of 49 readings were taken, of which 25 measurements were 25 ohms or less and 5 measured over 100 ohms, with the highest at 360 ohms. The average value of all these tests was 44.9 ohms. Two pole grounds were broken and no reading was indicated. There is no specific code requirement for ground resistance values on a multi-grounded neutral system having at least 4 grounds per mile. (DH-07, Q-DH-001)

Current measurements were taken on each ground conductor at the same time. One broken ground connection was found and reportedly repaired at a pole with a service to a cable TV amplifier box. Otherwise, the reported current readings on these grounds were minimal, generally below 10 milliamps, except near the substation where pole 9/51 measured 151 milliamps. Theoretically, the ground current should be zero; however we found nothing unusual in the reported current readings.

PSNH previously tested the ground resistance on the 3W2 circuit in March 2000. The ground resistance can vary for a number of reasons, including the moisture content of the soil at the time of the test. The January 2004 ground test on the 3W2 circuit was similar to the previous test and did not show significant changes in the values. A comparison of the March 2000 and January 2004 readings is shown in the following table:

TABLE 4.2.4
GROUND TEST COMPARISON

<u>STREET</u>	<u>POLE</u>	<u>JAN 2004 OHMS</u>	<u>JAN 2004 CURRENT (MA)</u>	<u>MARCH 2000 OHMS</u>	<u>MARCH 2000 CURRENT (MA)</u>
No. Amherst Rd.	842/21	67	3	53	0
No. Amherst Rd.	842/25	30.4	2	38	1
No. Amherst Rd.	842/29	30	0	101	0
No. Amherst Rd.	842/30	38	0	109	0
No. Amherst Rd.	842/31	13	0	113	0
No. Amherst Rd.	842/34	9	0	109	0
No. Amherst Rd.	842/35	17	0	63	0
No. Amherst Rd.	842/36	12	0	63	0
No. Amherst Rd.	842/37	3	1	45	0
No. Amherst Rd.	842/38	29	3	31	2
No. Amherst Rd.	842/39	4.9	5	150	2
No. Amherst Rd.	842/40	0.27	0	41	5
No. Amherst Rd.	842/41	164	2	64	3
No. Amherst Rd.	842/99	190	1	95	1
No. Amherst Rd.	842/101	325	1	126	2
Liberty Hill Rd.	10/23	30	5	22	8
Liberty Hill Rd.	10/24	106	0	121	0
Liberty Hill Rd.	10/25	56	1	24	4
AVERAGE OHMS		62.5		76	

F5 PSNH tested the ground resistance at 49 locations on the 3W2 distribution circuit and the results were comparable with the previous test four years earlier. No unusual readings were reported.

R1 PSNH should take ground resistance readings on a periodic basis to verify grounding integrity on distribution circuits. Investigation and remediation should be taken at locations where the resistance values are significantly higher than the previous test.

4.3 CUSTOMER COMPLAINT RESPONSES

The Vantage Report described the PSNH process from initial customer complaint through completion of a Trouble Report and Unsatisfactory Performance of Equipment Report (TRUPER) that summarized the problems found and the corrective actions taken. One finding indicated that customers were not familiar with utility terminology regarding power abnormalities and this resulted in an inaccurate problem description.

Customers should not need to learn a new language to communicate their concerns and the utility should consider using additional or different types of questions on the Trouble Call Entry form. The present form is well suited to certain problems regarding power failure, wires down, tree limbs on wires, fire, accident and similar situations. It does not appear to address power quality issues beyond bright/dim lights, flicker or “other” categories. (DH-01, Q-DH-003, Attachment 3A)

F6 PSNH maintains a documented record on customer complaints and their responses; however the data collection form does not appear to include specific items to help identify the cause of some customer power quality problems.

R2 PSNH should periodically review the questions used to obtain problem information from customers and revise the questions, if required, to better define power quality issues for corrective action.

SECTION 5

NHPUC VOLTAGE REQUIREMENTS AND UTILITY STANDARDS

5.1 APPLICABLE RULES AND REGULATIONS

Electric utilities in New Hampshire are regulated by the Public Utility Commission under state law. The *New Hampshire Code of Administrative Rules, Chapter PUC 300 Rules and Regulations for Electric Service* define the rules that apply to any electric utility operating in New Hampshire.

Paragraph PUC 304.02, Voltage Variation, lists the various service voltage configurations and the upper and lower permissible limits that the utility must maintain at the utility's service terminals for each customer. This report is primarily focused on residential customer concerns, so the allowable range for a nominal 120 volt service is between 110 and 125 volts. Similar ranges are permitted for other service voltages; however the permissible limits are the same percentages, adjusted for voltage. In other words, the allowable lower limit is 92% and the maximum limit is 104%, regardless of nominal service voltage.

There are five exceptions to these limits:

1. Weather or other action of the elements.
2. Infrequent fluctuations not exceeding five minutes in duration.
3. Arising from low power factor operation of the affected customer's equipment.
4. Arising from unbalanced operation of the affected customer's equipment.
5. Arising from failure or maintenance on equipment.

For most single phase 120/240 volt residential customers, this means that the service voltage must be supplied at a level between 110 and 125 volts for 120 volt equipment and between 220 and 250 volts for 240 volt equipment. In each case, the voltage measurement is a five minute average to accommodate instantaneous variations that may be caused by equipment starting, utility operations or other momentary events.

5.2 UTILITY OPERATION TO COMPLY WITH NHPUC VOLTAGE REQUIREMENTS

PSNH provides and maintains voltage regulation equipment to provide service voltage within these limits. The utility records indicate that voltage surveys are performed with recording meters at various customer locations in response to a complaint. Data for each affected customer was recorded on the E-1 Quarterly Report on Voltage Complaint Tests form and submitted to the PUC.

5.3 IMPACTS ON POWER QUALITY WITHIN THE CUSTOMER'S PREMISES

5.3.1 SERVICE ENTRANCE WIRE VOLTAGE DROP

The service entrance wires, or cables, have a certain value of resistance based on the type of conductor material, length and wire size. Based on Ohm's law, the voltage drop over a length of wire is the product of current and resistance. If the current flow is zero, there is no voltage drop and the voltage will be identical at both the source and load ends. As more current flows through the wire, the load voltage will decrease as the voltage drop increases.

In other words, the sum of the load voltage and the service voltage drop equals the source voltage. As the service voltage drop increases, the load voltage decreases.

Transformer load losses may contribute to the overall voltage drop at the customer location, especially if the customer total load is close to, or exceeds, the transformer rating.

5.3.2 VOLTAGE STABILITY

A customer's service voltage is not constant and may vary continuously over a range of values. This is the overall effect of many individual customers turning equipment on and off. It is unrealistic to expect that each customer will see a constant 120 volts at every hour of the day or night. Voltage testing is not simple because of continuous load variation on the utility system.

In addition to normal utility voltage variations, there are instantaneous variations caused by the customer starting certain equipment, such as a motor. The instantaneous inrush current to a motor may be 5 or 6 times the running current. When this sudden current flows through the service wires, the voltage drop over the service wires will instantaneously increase then return to the previous value. As a result, the voltage at the electrical panel will suddenly decrease (sag) and then return to normal. An electrical service may have functioned successfully for years, but the addition of new customer loads, such as central air conditioning, could cause new voltage sag problems.

The typical indication of voltage sag is a visible instantaneous reduction in the light output of a lamp, commonly called “lamp flicker.” Flicker is not a problem by itself, but is a symptom of the instantaneous voltage drops. If the occurrence of individual flicker events become too frequent, then the overall effect may ultimately become objectionable. The nuisance effect is highly subjective and there is no absolute standard of irritability.

The instantaneous current inrush at the customer’s location is most likely to affect other customers supplied by the same utility transformer. It will also reflect back on the utility distribution system to some degree, but the effect on other customers should be minimal. Typically, these problems are solved by upgrading transformer and service wire sizes to the affected customer.

5.4 INTERNAL VOLTAGE DROP CRITERIA

The National Electrical Code, NFPA-70, 2002 Edition, published by the National Fire Protection Association was adopted by the State of New Hampshire for all electrical installations, as defined by RSA 319-C:2, III. Article 210.19 (A) (1) FPN No. 4 states that conductors should be sized for a maximum voltage drop of 3% for branch circuits, 2% for feeders, or a combined 5% maximum voltage drop to the farthest outlet for power lighting or combination loads. Article 90.5 defines fine print notes (FPN) as explanatory materials that are not mandatory requirements.

This 5% maximum voltage drop is a guideline to minimize losses and maintain a reasonable level of efficiency between the service point and the farthest load. The potential

complication of this loss added to a low service voltage could cause equipment to operate inefficiently.

In general, there is an allowance for voltage drop under IEEE criteria; 120 volts is the service voltage standard and 115 volts is the utilization equipment voltage standard. The difference between these two values is an allowance for voltage drop. Most electrical equipment is designed to operate over a typical voltage range of plus or minus 10 percent of the nominal voltage.

5.5 COMPARISON TO NATIONAL STANDARDS

New Hampshire utilities are currently required to maintain service within the low and high limits of 110 and 125 volts. These limits may have been appropriate at the time of adoption, but the power requirements of new electronic and computer equipment may require reevaluation of the voltage regulation standards.

A number of jurisdictions use the *ANSI C84.1 Electric Power Systems and Equipment – Voltage Ratings (60 HZ)* standard which defines the normal operating range as 120 volts +/- 5 percent, or from 114 volts to 126 volts. The major impacts of such a change would be to raise the minimum voltage limit by 4 volts, and increase the upper limit by one volt, at the meter and customer equipment. There may be a number of cost and operational impacts that would require an in-depth analysis by both the electric utilities and customer groups that are well beyond the scope of this report to forecast.

R3 The NHPUC should consider reviewing the voltage regulation criteria under Paragraph PUC 304.02 to determine if a modification to the present voltage limits would improve overall power quality.

SECTION 6

POWER MONITORING PROGRAM

6.1 GENERAL APPROACH

6.1.1 UTILITY MONITORING PROGRAM

Our major goal was to determine if the voltage variation on the distribution circuits was within the NHPUC voltage limits. We felt that monitoring and data collection on one 12.47 kV and one 34.5 kV distribution circuit would provide a sufficient sample to determine the extent of line voltage variations. The selection of the individual feeders is described in Section 6.2 and the specific metering data in Section 7, Utility Monitoring Results. This monitoring was scheduled in late June and early July when summer air conditioning loads were anticipated, since the summer peak loads exceed winter peak loads in the area.

6.1.2 CUSTOMER MONITORING PROGRAM

The utility monitoring program was intended to study the basic power quality issues related to utility operation up to the customer's meter. We chose to conduct additional sampling within customer electrical systems to determine if there were other conditions that could contribute to some of the reported concerns. A number of problems reported under the E-1 program were resolved to the customer's satisfaction, yet there are ongoing complaints where the solution has not been found, despite PSNH's attempts to solve the problems. We suspected that there may be various problems beyond the meter location that are not within the utility's legal jurisdiction to resolve. We found that customer equipment operation does affect the voltage as described in Section 8, Customer Monitoring Results.

6.2 DISTRIBUTION FEEDER SELECTION

A number of factors were considered in selecting the circuits for monitoring, including the number of customer concerns, voltage level, and professional judgment to include a representative customer sample. Using the Electrical Distribution Circuit Map, developed in the data collection phase, we selected the 3W2 and 322X10 circuits.

- Circuit 3W2, operating at 12,470 volts, originates at the Meetinghouse Road substation and extends westerly across the central part of town to serve a representative sample of residential and some commercial customers, including the Town Hall. This was our first choice for monitoring due to the number of ongoing customer concerns and the availability of pole ground test reports from March 2000.
- Circuit 322X10, operating at 34,500 volts, originates from a tap on the 322 transmission line at Donald Street and serves primarily residential customers in the north central part of town. This line was selected for the number of customer concerns and our desire to determine if there were differences between the 34.5 kV and 12.5 kV systems.

There is a common relationship between these selected circuits as both are supplied from the 322 transmission line operating at 34.5 kV. The Donald Street monitoring location is less than two miles up the transmission line from the Meetinghouse Road substation, where two transformers convert the 34.5 kV to 12.47 kV for the 3W1 and 3W2 circuits.

6.3 METERING EQUIPMENT

Our goal was to determine how the voltage on the utility primary circuit varied throughout the day and from day to day. This was accomplished by installing a meter on the pole top with the voltage sensing wires directly connected to the adjacent to the transformer. This configuration provided a direct indication of the primary voltage, since it was not possible to connect the meter directly to the 12.47 kV or 34.5 kV circuits.

We also wanted to measure the voltage within the customer's electrical system to determine how the voltage varied within the building. This would provide an indication of the voltage drop through the transformer and service wires since these losses increase with increased customer loads. These meters would be subject to additional branch circuit voltage drops caused by customer load variations.

Dufresne-Henry used three different types of meters to provide diversity in the data collection. We recognize that the technology and response speed of each instrument can provide different data for the same event; however it is also possible to capture data in one instrument that might be missed by another.

6.3.1 TWO MEGGER PA-9PLUS POWER QUALITY ANALYZERS (S/N: 2323P9 AND 2328P9)

These weatherproof recording meters were used to measure the voltage directly at the utility transformer terminals. The nonconductive, rain resistant, NEMA 4X enclosures were suitable for extended monitoring in outdoor locations and the operating power could be obtained through the voltage sensing wires.

The meters were programmed to continuously record the three phase, true RMS, utility voltage and identify any voltage deviations outside the 110 to 125 volt (and 254 to 288 volt) NHPUC limits. They were also set to capture any sub cycle voltage deviations and any total harmonic distortion exceeding 7%. Simply stated, we wanted to know how the voltage varied and if there were any abnormal voltage variations on the system.

We selected meter locations where PSNH was also able to install their metering equipment so that we could compare their results with our data. Upon verification, we would have a basis to accept other voltage data simultaneously measured by PSNH at other locations on the same power line.

A line crew from PSNH installed the meters on selected pole-top locations, immediately below their transformers, or inside pad-mounted transformer cabinets. The voltage sensing leads were connected directly to the transformer terminals to provide sampling directly from the utility system and simultaneously provide operating power to the meter. A data cable was installed from the meter to provide DH with a means to check data collection progress and modify recording parameters, if required, during the test period.

Both the installation and removal of these meters was witnessed by a DH engineer to verify that our requirements were met.

6.3.2 AEMC PQL-120 POWER QUALITY LOGGER (S/N: 09M46674DV)

This meter is designed to plug in to any 120 VAC outlet and it records 128 voltage samples per second for continuous true RMS voltage monitoring. In addition, it automatically captures the worst case surge and sag waveforms. This meter is somewhat limited and unable to capture voltage impulses above 140 Volts, however it will capture voltage waveforms of impulse disturbances.

We used this meter to monitor and record the voltage on a continuous basis inside selected customer locations.

6.3.3 CUTLER-HAMMER POWER WATCH PW-200 (S/N: 18549)

This meter is designed to record up to 4,000 individual events while plugged in to a 120 VAC outlet. It will capture and identify any voltage deviations and time durations outside programmed limits. It is capable of detecting up to 2,500 Volt peak events lasting as short as 1 microsecond.

We used this meter inside selected customer locations, simultaneously with the PQL-120 instrument, to identify voltage sags, surges and impulse events.

6.3.4 AEMC 3730 CLAMP-ON GROUND RESISTANCE TESTER

This meter is designed to provide direct readings of ground resistance of a single ground connection on a multi-grounded system. It also measures current to identify any circulating currents on the ground conductor being tested.

We used this meter to determine ground resistance at selected poles. Ground resistance measurements were taken on both the pole ground wire and each guy wire, as the guys sometimes have a lower ground resistance than the pole ground because of the larger surface area of the metal anchor. This metering was primarily for spot checking and was not used for data collection beyond the limited results shown on the Monitoring Program Maps.

6.4 INTERPRETATION OF METERING RESULTS

6.4.1 TERMINOLOGY

The following terms are presented to provide a common definition of various electrical terms used in this report. They are not intended to be technically rigorous and have been simplified to promote understanding by readers who may be unfamiliar with electrical concepts. The goal is to provide a basic comprehension level for a mixed audience.

- Sag – A short duration voltage decrease lasting for a few seconds or less.
- Swell – A short duration voltage increase lasting for a minute or less.
- Impulse – A sudden instantaneous change in the voltage waveform lasting for less than one cycle of the 60 HZ (cycle-per-second) alternating voltage waveform. This could alternatively be called a spike or transient.
- Overvoltage – a voltage increase lasting for more than a minute.
- Flicker – A momentary voltage variation of sufficient magnitude and duration to be observed as a visible change in lamp brightness level.

6.4.2 METERING RESULTS

Section 7 describes the formal monitoring program conducted to determine utility compliance with NHPUC voltage requirements.

Section 8 describes additional monitoring conducted within selected customer locations to obtain additional information on voltage variations on the customer side of the electric meter.

The voltage charts and tables provided by PSNH were prepared by the utility for this report.

SECTION 7

UTILITY MONITORING RESULTS

7.1 CIRCUIT 3W2 METERING PROGRAM

The metering program is described on Circuit 3W2 Monitoring Program Description and Circuit 3W2 Monitoring Program Map. Meter readings were taken between June 25 and July 1, 2004 at the following meter locations:

- Bedford Town Hall, North Amherst Road – The existing PSNH PMI monitor was augmented by the DH analyzer which was installed below the transformers on pole.
- McKelvie School, County Road - The existing PSNH PMI monitor was augmented by the DH analyzer which was installed below the transformers on pole.
- Rosewell Road – PSNH installed a single phase RPM voltage monitor at Transformer #T5 to record conditions near the end of the circuit fed via Campbell Road.
- Greeley Hill Road - PSNH installed a single phase RPM voltage monitor at Transformer #T2 to record conditions near the end of the circuit fed via North Amherst Road.
- Ground resistance was tested at the test metering locations and capacitor banks and regulators were disconnected per the testing schedule.

7.1.1 BEDFORD TOWN HALL, NORTH AMHERST ROAD

7.1.1.1 *DH PA-9Plus Power Analyzer*

The meter was installed on North Amherst Road pole 842/25 and connected a 208Y/120 volt transformer bank. The voltage leads measured a nominal 120 volts phase to neutral on each of the three phases. The NHPUC limits for this voltage is 110 volts minimum, 120 volts nominal and 125 volts maximum. The measurements are tabulated in the following table.

TABLE 7.1.1.1
DH PA-9PLUS POWER ANALYZER AT TOWN HALL

RECORDING PERIOD	START	6/25/04	10:40 AM
	STOP	7/1/04	9:05 AM
	Minimum Volts	Average Volts	Maximum Volts
NHPUC Limit	110	120	125
Phase A	113.0	120.7	122.8
Phase B	113.4	121.0	122.8
Phase C	112.0	119.7	121.8

The voltage remained within NHPUC limits of 110 to 125 Volts as measured at the pole mounted utility service transformers at the Town Hall.

The monitoring at this location was conducted in two stages with the first between June 25 and June 28 where the meter was programmed to monitor on a one cycle basis and record voltages every two minutes. The meter data was then checked and the recording interval was changed to 30 seconds for a second monitoring period between June 28 and July 1. This intermediate change was made since we were not certain of the quantity of data that would be recorded relative to the memory capacity of the meter.

There were numerous short term voltage sag events observed during the monitoring period and these sags are included within the minimum voltages indicated in the above table. These are discussed in more detail in Section 8 under Customer Monitoring Results.

CIRCUIT 3W2

MONITORING PROGRAM DESCRIPTION

CONDUCTED JUNE 25, 2004 TO JULY 1, 2004

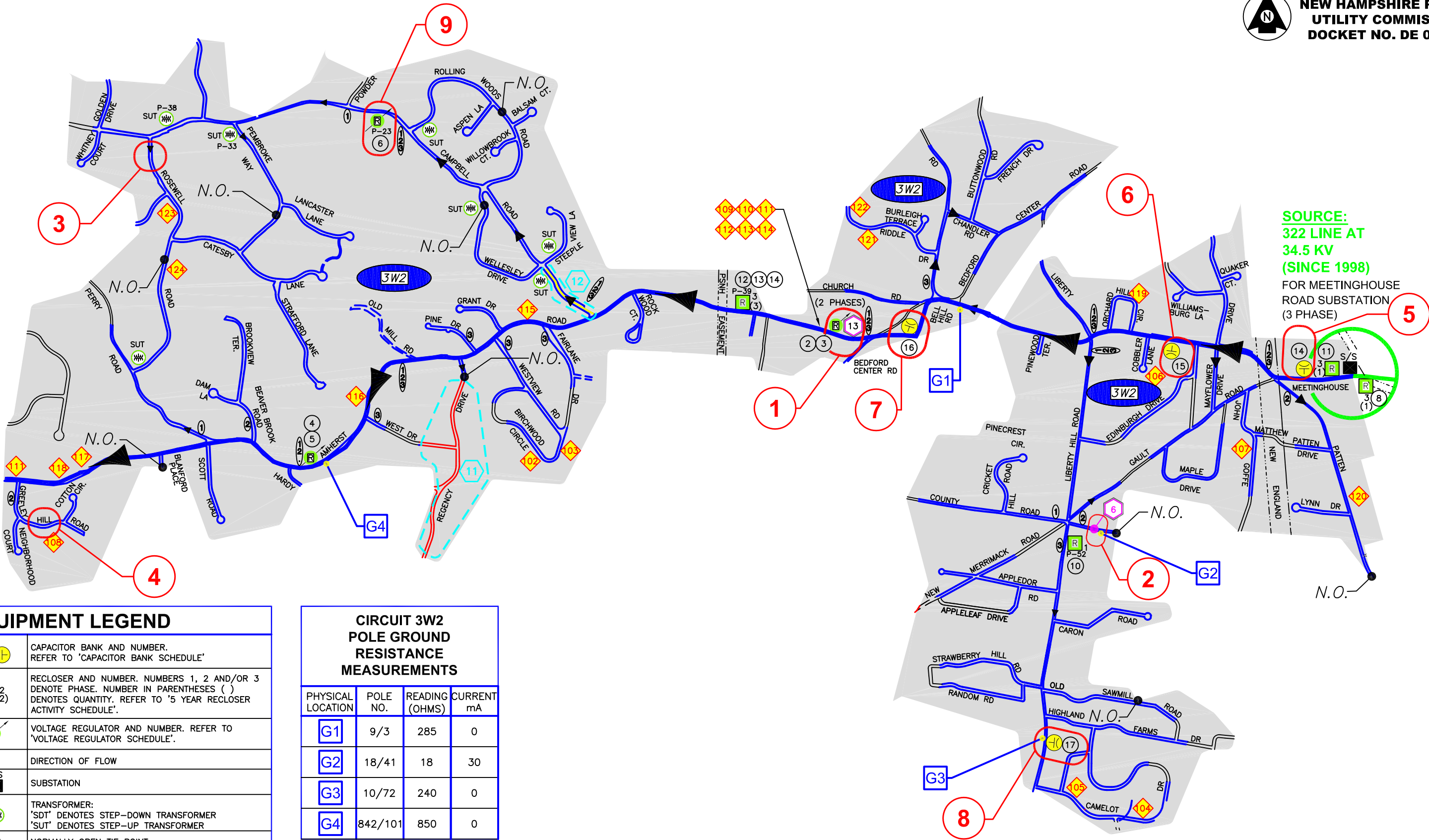
SEQUENCE NUMBER	PHASE	STREET NAME	EQUIPMENT DESCRIPTION	DESCRIPTION OF WORK PERFORMED
①	3Ø	BEDFORD TOWN HALL NORTH AMHERST ROAD POLE NO. 842/25	PSNH 3Ø PMI MONITOR DH 3Ø MEGGER MONITOR	PSNH INSTALLED DH RECORDING METER ON POLE AND PSNH METER INSIDE TOWN HALL ELECTRICAL PANEL.
②	3Ø	McKELVIE SCHOOL ON COUNTY ROAD POLE NO. 18/40	PSNH 3Ø PMI MONITOR DH 3Ø MEGGER MONITOR	PSNH INSTALLED DH METER ON POLE AND REPROGRAMMED EXISTING PSNH METER ON INSIDE PANEL.
③	#1 PHASE	ROSEWELL ROAD PAD MOUNTED TRANSFORMER T5	PSNH 1Ø RPM MONITOR	PSNH INSTALLED MONITOR AT TRANSFORMER.
④	#1 PHASE	GREELEY HILL ROAD PAD MOUNTED TRANSFORMER T2	PSNH 1Ø PMI MONITOR	PSNH INSTALLED MONITOR AT TRANSFORMER.
⑤	3Ø	MEETINGHOUSE ROAD POLE NO. 9/52	EXISTING CAPACITOR BANK NO. 14	PSNH DISCONNECTED CAPACITOR ON JUNE 28 AT 9:00 AM AND RECONNECTED ON JUNE 29 AT 8:45 AM.
⑥	3Ø	MEETINGHOUSE ROAD POLE NO. 9/29	EXISTING CAPACITOR BANK NO. 15	PSNH DISCONNECTED CAPACITOR ON JUNE 28 AT 9:30 AM AND RECONNECTED ON JUNE 29 AT 9:00 AM.
⑦	3Ø	NORTH AMHERST ROAD POLE NO. 842/16	EXISTING CAPACITOR BANK NO. 16	PSNH DISCONNECTED CAPACITOR ON JUNE 28 AT 10:00 AM AND RECONNECTED ON JUNE 29 AT 9:40 AM.
⑧	#1 PHASE	LIBERTY HILL ROAD POLE NO. 10/72	EXISTING CAPACITOR BANK NO. 17	PSNH DISCONNECTED CAPACITOR ON JUNE 28 AT 10:30 AM AND RECONNECTED ON JUNE 29 AT 9:18 AM.
⑨	3Ø	CAMPBELL ROAD POLE NO. 92/23	EXISTING REGULATOR NO. 6	PSNH BYPASSED REGULATOR ON JUNE 29 AT 10:45 AM AND RECONNECTED ON JUNE 30 AT 8:45 AM.

GENERAL NOTES:

- A) DH PROVIDED PSNH WITH TWO, 3-PHASE (3Ø) 'MEGGER PA-9 PLUS' MONITORS FOR INSTALLATION BY PSNH.
- B) PSNH AND DH COORDINATED TIME CLOCK SETTINGS ON ALL MONITORS TO PERMIT COMPARISON OF RESULTS.
- C) PSNH CALIBRATED ALL MONITORS TO READ AND RECORD ALL INSTANTANEOUS EVENTS. HARMONICS READINGS WERE NOT REQUIRED.
- D) PSNH RECORDED AT TWO, 3-PHASE (3Ø) LOCATIONS AND TWO, 1-PHASE (1Ø) LOCATIONS
- E) SEE TABLE FOR POLE GROUND RESISTANCE MEASUREMENTS (G1 - G4).



FIGURE 7.1A



EQUIPMENT LEGEND	
	CAPACITOR BANK AND NUMBER. REFER TO 'CAPACITOR BANK SCHEDULE'
	RECLOSER AND NUMBER. NUMBERS 1, 2 AND/OR 3 DENOTE PHASE. NUMBER IN PARENTHESES () DENOTES QUANTITY. REFER TO '5 YEAR RECLOSER ACTIVITY SCHEDULE'.
	VOLTAGE REGULATOR AND NUMBER. REFER TO 'VOLTAGE REGULATOR SCHEDULE'.
	DIRECTION OF FLOW
	SUBSTATION
	TRANSFORMER: 'SDT' DENOTES STEP-DOWN TRANSFORMER 'SUT' DENOTES STEP-UP TRANSFORMER
	NORMALLY OPEN TIE POINT
	LOCATION OF CUSTOMER CONCERN REFER TO 'CUSTOMER CONCERN SCHEDULE'
	DENOTES LINE PHASE OR PHASES
	CIRCUIT UPGRADE/TRANSFER. REFER TO 'CIRCUIT UPGRADE/TRANSFER SCHEDULE'.

CIRCUIT 3W2 POLE GROUND RESISTANCE MEASUREMENTS			
PHYSICAL LOCATION	POLE NO.	READING (OHMS)	CURRENT mA
G1	9/3	285	0
G2	18/41	18	30
G3	10/72	240	0
G4	842/101	850	0

CIRCUIT 3W2
MONITORING PROGRAM MAP
CONDUCTED JUNE 25, 2004 TO JULY 1, 2004



FIGURE 7.1B

FIGURE 7.1.1.1A RMS Voltage Recording at Town Hall during Monitoring Period 6/25 - 6/28

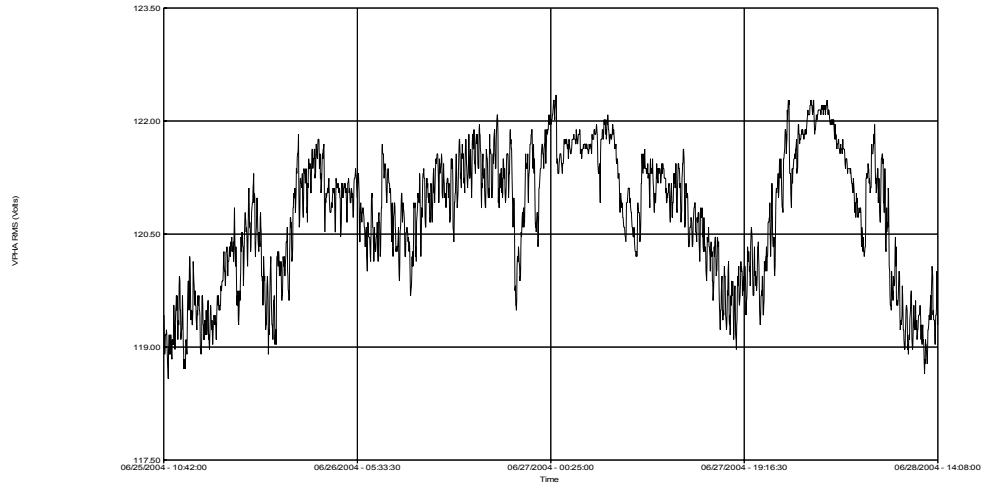
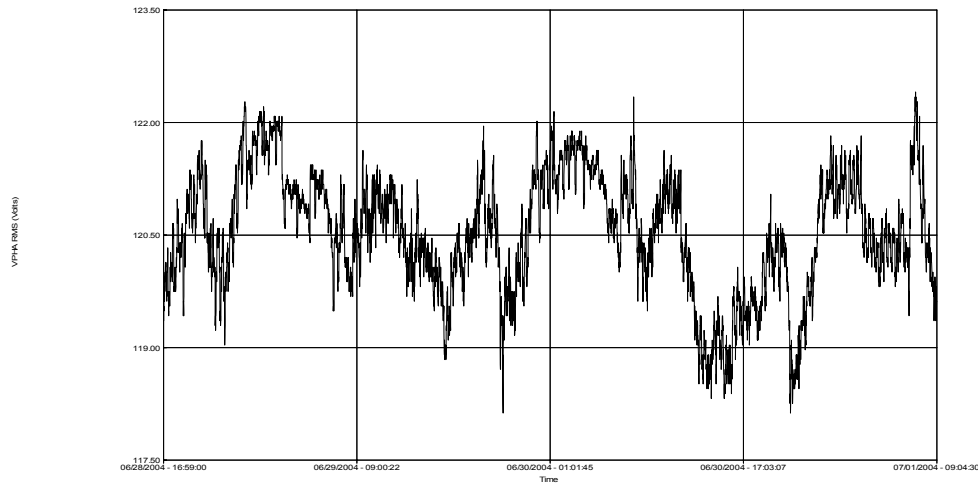


FIGURE 7.1.1.1B RMS Voltage Recording at Town Hall during Monitoring Period 6/28 - 7/1



A total of 12 harmonic events were logged, of which 7 were captured by one or both of the AEMC and CH meters. These impulse events appear to be related to capacitor switching (see Section 8 for more information).

7.1.1.2 PSNH PMI Monitor

The PMI meter was connected to a power panel inside the building and recorded similar, or slightly lower, values than at the pole. It also was affected by load changes within the office as equipment cycled on and off. Data from this meter indicated numerous voltage sags, which were also captured by other meters. Utilization voltage at the panel was generally in the range of 115 to 123 volts, with some voltage sags down to 108 volts. The raw data from PSNH shows the relative voltage distribution.

Table 7.1.1.2A shows the number of cycles spent at each voltage level during 6/25-7/1 monitoring period.

**TABLE 7.1.1.2A
TOWN HALL PANEL**

VOLTAGE	PH1	PH2	PH3
107	0	0	0
108	18	7	0
109	70	52	21
110	139	134	110
111	146	166	176
112	142	123	151
113	106	84	92
114	142	68	85
115	11539	104	98
116	365736	229	244
117	1951984	33369	16306
118	4823559	990500	372989
119	9523670	3979829	3608199
120	8584735	7651476	8124975

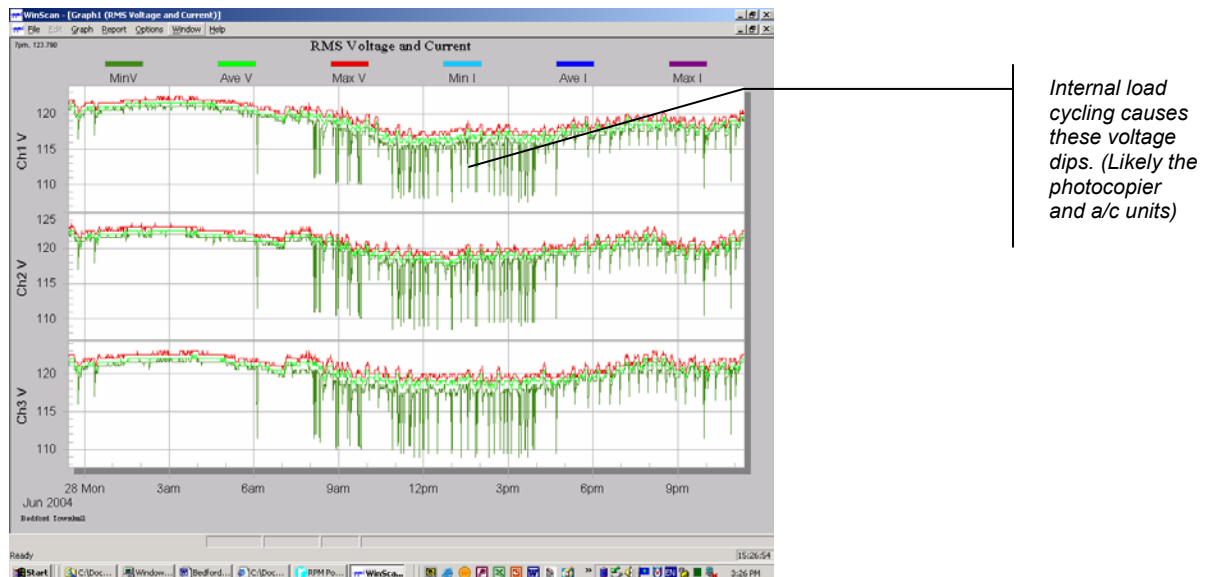
VOLTAGE	PH1	PH2	PH3
121	5006296	9050857	11598295
122	508255	8475724	6900562
123	2	593817	154236
124	0	0	0

A weighted average of the voltage distribution is summarized in the following table:

TABLE 7.1.1.2B
PSNH PMI MONITOR AT TOWN HALL

	MINIMUM VOLTS	AVERAGE VOLTS	MAXIMUM VOLTS
NHPUC Limit	110	120	125
Phase A	108	119.3	123
Phase B	108	120.7	123
Phase C	109	120.7	123

FIGURE 7.1.1.2 Town Hall panel during the 6/28 9:00/9:30/10:00/10:30 capacitor switching on 3W2



Voltage sags and dips were observed during the hours when the office was open (see Section 8).

7.1.1.3 Ground Resistance

The ground resistance at pole 842/25 on North Amherst Road was 1.2 ohms with a ground current of 3.15 Amps at the time of the meter installation. The ground currents in Table 4.2.4 for this pole are in the range of 1 to 2 milliamps for comparison.

R4 PSNH should investigate the cause of the ground reading of 3.15 amps at pole 842/25 at the Town Hall

7.1.2 MCKELVIE SCHOOL, COUNTY ROAD

7.1.2.1 DH PA-9Plus Power Analyzer

The meter was installed on County Road pole 18/40 and connected a 208Y/120 volt transformer bank. The voltage leads measured a nominal 120 volts phase to neutral on each of the three phases. The NHPUC limits for this voltage is 110 volts minimum, 120 volts nominal and 125 volts maximum. The measurements are tabulated in the following table.



TABLE 7.1.2.1
DH PA-9PLUS POWER ANALYZER AT MCKELVIE SCHOOL

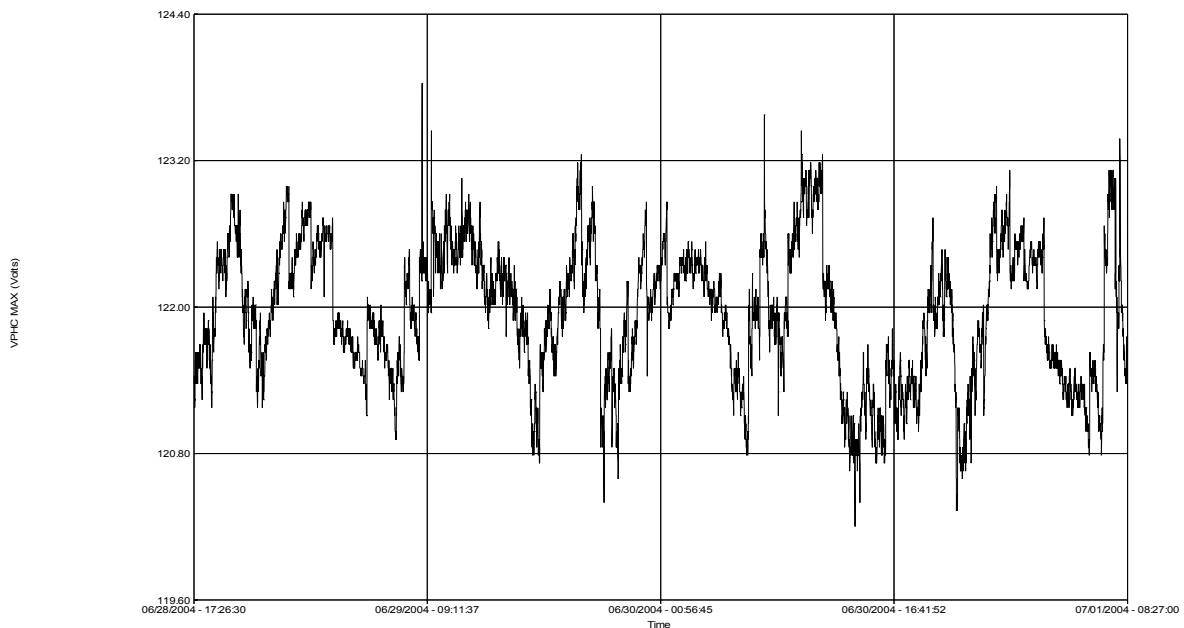
RECORDING PERIOD	START	6/28/04	5:26 PM
	STOP	7/1/04	8:27 AM
	Minimum Volts	Average Volts	Maximum Volts
NHPUC Limit	110	120	125
Phase A	116.6	120.0	121.7
Phase B	116.9	121.4	122.9
Phase C	116.8	121.8	123.8

Voltage remained within NHPUC limits of 110 to 125 Volts.

The monitoring was conducted in two stages with the first between June 25 and June 28 where the meter was programmed to monitor on a one cycle basis and record voltages every

two minutes. The meter data was then checked and the recording interval was changed to 30 seconds for a second monitoring period between June 28 and July 1. This intermediate change was made since we were not certain of the quantity of data that would be recorded relative to the memory capacity of the meter. The meter malfunctioned and there was no usable data recorded from the June 25 to June 28 period.

Figure 7.1.2.1 RMS Voltage Recording at McKelvie School during Monitoring Period



A total of 10 harmonic events were logged on this feeder, of which 9 were captured by both of the PA-9Plus meters at the same time. These appear to be impulse events related to capacitor switching on the primary system since they affected both meters.

7.1.2.2 PSNH PMI Monitor

The PMI meter was connected to the meter test switch at the building and recorded similar, or slightly higher, values than at the pole. The raw data from PSNH shows the relative voltage distribution:

Number of cycles spent at each voltage level during the monitoring period:

TABLE 7.1.2.2A
MCKELVIE SCHOOL PANEL

VOLTAGE	PH1	PH2	PH3
117	0	0	0
118	0	0	15
119	0	0	1611947
120	602	65670	6793300
121	3018886	6799217	13441685
122	15442810	18316806	8800248
123	12830671	6257196	793847
124	148072	2153	0
125	1	0	0

A weighted average of the voltage distribution is summarized in the following table:

TABLE 7.1.2.2B
PSNH PMI MONITOR AT MCKELVIE SCHOOL

	MINIMUM VOLTS	AVERAGE VOLTS	MAXIMUM VOLTS
NHPUC Limit	110	120	125
Phase A	120	122.3	125
Phase B	120	122.0	124
Phase C	118	121.0	123

7.1.2.3 Ground Resistance

The ground resistance at pole 18/40 on County Road was varying so three measurements were taken. The ground resistance readings were 4.6 ohms, 10.7 ohms and 11.1 ohms and the ground current was 34 mA at the time of the meter installation.



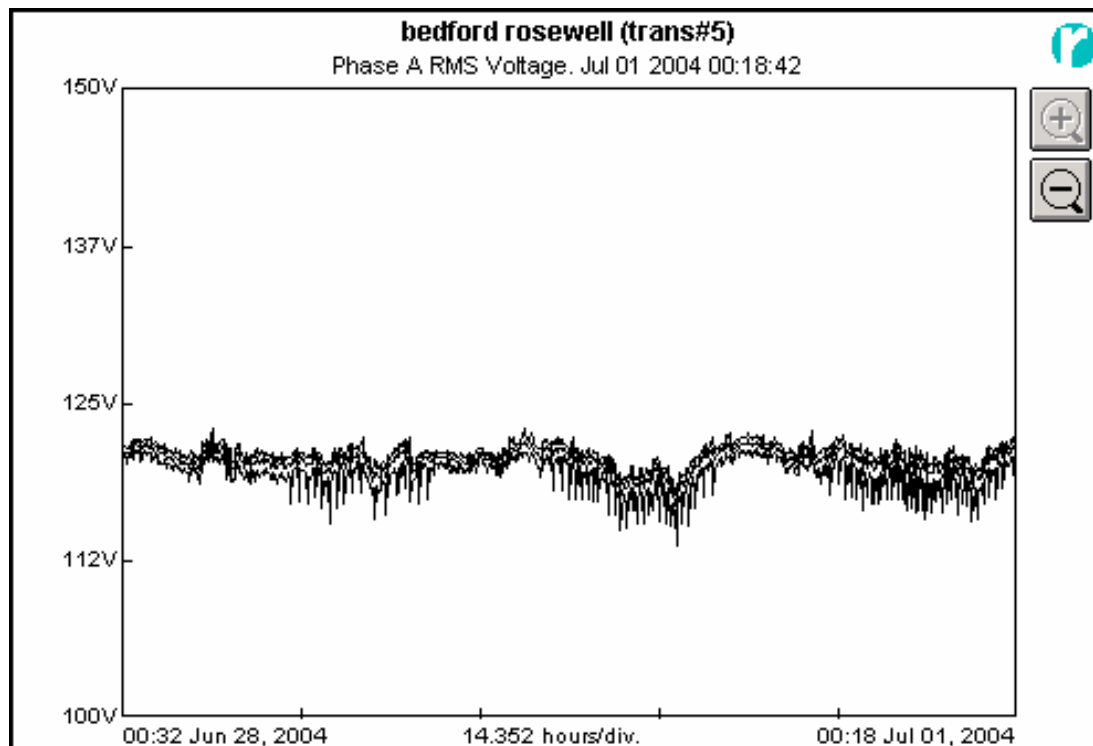
7.1.3 ROSEWELL ROAD TRANSFORMER #T5

7.1.3.1 PSNH RPM Monitor

PSNH installed an RPM Voltage Monitor inside pad-mounted transformer T5. The data indicated that the voltage remained within NHPUC limits for the duration of the test period, including the time when the capacitors and voltage regulator were removed from service.

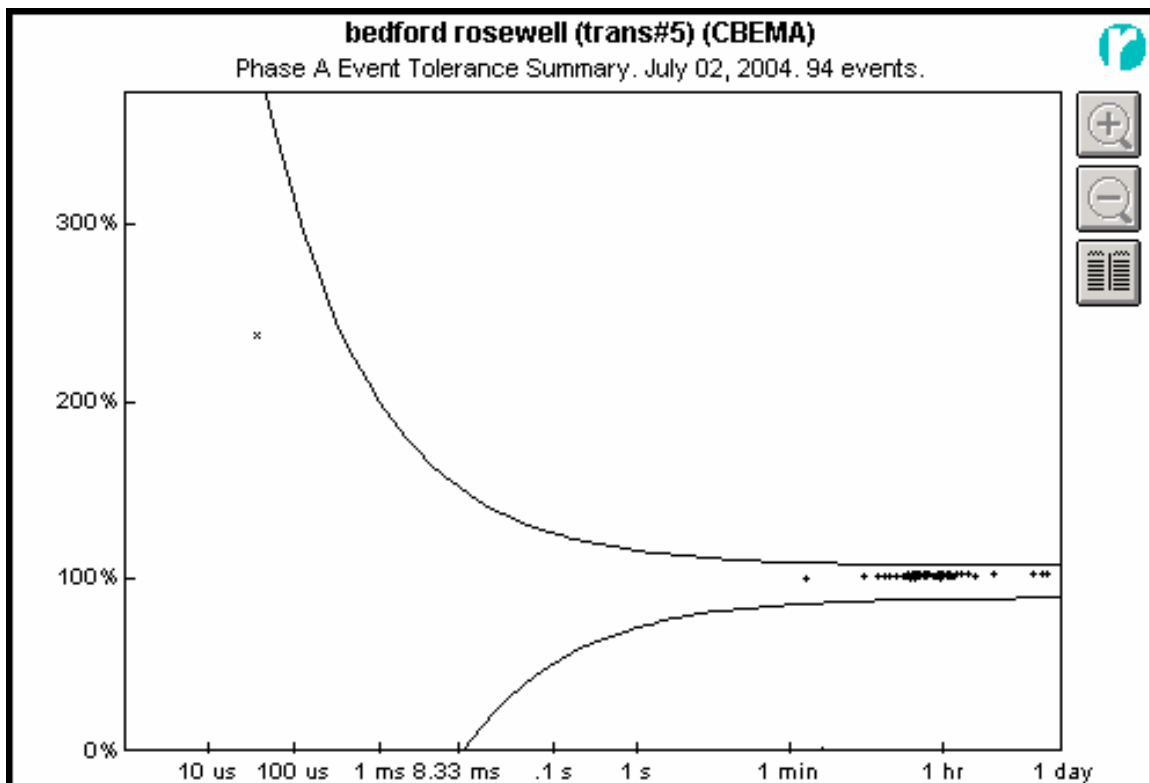


FIGURE 7.1.3.1A Bedford Rosewell (Transformer #5)



The individual voltage events during the capacitor and regulator removal periods remained within the CBEMA curve limits, a standard developed by computer and business equipment manufacturers to define allowable power quality. The CBEMA curve is now known as the 1996 ITI Curve, as developed by the Information Technology Industry Council, and specifies that equipment should be able to withstand voltage variations of +/- 10% for durations over 10 seconds. The following graph shows that the voltage remains within these requirements.

FIGURE 7.1.3.1B Bedford Rosewell (Transformer #5) (CBEMA)



7.1.3.2 Ground Resistance

The ground resistance at transformer T5 was 0.19 ohms with a ground current of 234 mA at the time of meter installation.



7.1.4 GREELEY HILL ROAD TRANSFORMER #T5

7.1.4.1 PSNH PMI Monitor

PSNH installed a PMI Voltage Monitor inside pad-mounted transformer T2. The data indicated that the voltage remained within a range of 115 to 124 volts for the duration of the test period, including the time when the capacitors and voltage regulator were removed from service.

Greeley Hill Friday – Sunday (waveform scan window +/-10%) 6/25-6/27 (1 waveform caught @disconnect) Number of cycles spent at each voltage level.

TABLE 7.1.4.1A
GREELEY HILL ROAD

VOLTAGE	PH1	PH2
114	0	0
115	25	0
116	58	0
117	869	0
118	136630	43
119	574228	715
120	1503229	320346
121	3265851	1638788
122	3181277	4587419
123	737082	2839793
124	2	12147
125	0	0

A weighted average of the voltage distribution is summarized in the following table:

TABLE 7.1.4.1B
PSNH PMI MONITOR AT GREELEY HILL ROAD

	MINIMUM VOLTS	AVERAGE VOLTS	MAXIMUM VOLTS
NHPUC Limit	110	120	125
Phase A	115	121.2	124
Phase B	118	122.1	124

7.1.4.2 Ground Resistance

The ground resistance at transformer T2 was 0.10 ohms with a ground current of 139 mA at the time of meter installation.

7.1.5 CAPACITOR BANKS

PSNH opened capacitor banks to remove them from the line at the following locations and times. The voltage is lower after the capacitors were disconnected, but not significantly. This indicates that the feeder is stable in its basic configuration.

TABLE 7.1.5
CAPACITOR BANKS

LOCATION	POLE NUMBER	CAPACITOR SIZE KVAR	MONDAY 6/28/04 TIME OFF	TUESDAY 6/29/04 TIME ON
Meetinghouse Rd.	9/52	300	9:00 AM	8:45 AM
Meetinghouse Rd.	9/29	300	9:30 AM	9:00 AM
N. Amherst & Bedford Center Rd.	842/16	300	10:00 AM	9:40 AM
Liberty Hill Rd.	10/72	100	10:30 AM	9:18 AM

7.1.6 VOLTAGE REGULATOR

PSNH manually set the voltage regulator, on Campbell Road pole 92/23, to the neutral position and manually bypassed the unit to remove it from service at 10:45 AM on Tuesday June 29, 2004. The regulator was restored to service at 8:45 AM on Wednesday June 30, 2004.

Only the Rosewell Road voltage monitor is affected by this regulator and no significant change was observed during the period when the regulator was off-line. This indicates that the basic distribution system was adequate to maintain the voltage within limits for the line loads experienced during this test period. The regulator function is to maintain the line voltage within closer limits than would be the case without the regulator.

7.1.7 RECLOSER OPERATION

PSNH took readings on the three reclosers located on North Amherst Road pole 842/39 at the start of the test period at 11:10 AM on June 25 and again at the end of the test period at 9:45 AM on July 1, 2004. No operations were recorded on the reclosers during the test period.

7.1.8 SUMMARY OF CIRCUIT 3W2

Based on the results detailed above, the following conclusion can be made:

F7 The voltage on the 3W2 circuit remained within NHPUC limits during the monitoring period.

7.2 CIRCUIT 322X10 METERING PROGRAM

The metering program is described on Circuit 322X10 Monitoring Program Description and Circuit 322X10 Monitoring Program Map. Meter readings were taken between July 9 and July 14, 2004 at the following meter locations:

- Donald Street, near the tap from the 322 line - PSNH installed both their PMI monitor and the DH analyzer below the transformers on pole 25/57Y.
- Riddle Brook Elementary School, New Boston Road - The existing PSNH PMI monitor was augmented by the DH analyzer which was installed on the three phase service pole below the transformers.
- Stonehenge Road – PSNH installed a PMI monitor on the top of pole 314/4.
- Rumford Lane - PSNH installed a single phase RPM voltage monitor in the first pad mount transformer off McAllister Road pole 11/272.
- Spring Hill Road – PSNH installed a single phase RPM voltage monitor in the pad mount transformer off pole 2/47.

CIRCUIT 322X10

MONITORING PROGRAM DESCRIPTION

CONDUCTED JULY 9 TO JULY 15, 2004

SEQUENCE NUMBER	PHASE	STREET NAME	EQUIPMENT DESCRIPTION	DESCRIPTION OF WORK PERFORMED
①	3 ϕ	DONALD STREET (NEAR CIRCUIT TAP) POLE NO. 25/57Y	PSNH 3 ϕ PMI MONITOR DH 3 ϕ MEGGER MONITOR	PSNH INSTALLED DH AND PSNH RECORDING METERS ON POLE
②	3 ϕ	RIDDLE BROOK ELEMENTARY SCHOOL, NEW BOSTON ROAD. PAD MOUNTED TRANSFORMER T1	PSNH 3 ϕ PMI MONITOR DH 3 ϕ MEGGER MONITOR	PSNH INSTALLED DH METER INSIDE PAD MOUNTED TRANSFORMER ADJACENT TO EXISTING PSNH METER WHICH WAS REPROGRAMMED.
③	#1 PHASE	STONEHENGE ROAD POLE NO. 314/4	PSNH 1 ϕ PMI MONITOR	PSNH INSTALLED MONITOR ON POLE.
④	#1 PHASE	RUMFORD LANE PAD MOUNTED TRANSFORMER T1	PSNH 1 ϕ PMI MONITOR	PSNH INSTALLED MONITOR AT TRANSFORMER.
⑤	#2 PHASE	SPRING HILL ROAD PAD MOUNTED TRANSFORMER T2	PSNH 1 ϕ RPM HIGH SPEED MONITOR	PSNH INSTALLED MONITOR AT TRANSFORMER.
⑥	3 ϕ	NEW BOSTON ROAD POLE NO. 25/93	EXISTING CAPACITOR BANK NO. 4	PSNH DISCONNECTED CAPACITOR ON JULY 13 AT 8:30 AM AND RECONNECTED ON JULY 14 AT 10:40 AM.
⑦	#1 PHASE	STONEHENGE ROAD POLE NO. 314/3 AND POLE NO. 314/4	GROUNDING TEST	TESTING AT TWO EXISTING POLE LOCATIONS: 1. CHECKED EXISTING GROUND RESISTANCE. 2. INSTALLED SECOND GROUND ROD, CONNECTED TO EXISTING GROUND AND CHECKED GROUND RESISTANCE. 3. REMOVED SECOND GROUND ROD AND RE-CHECKED GROUND RESISTANCE.

GENERAL NOTES:

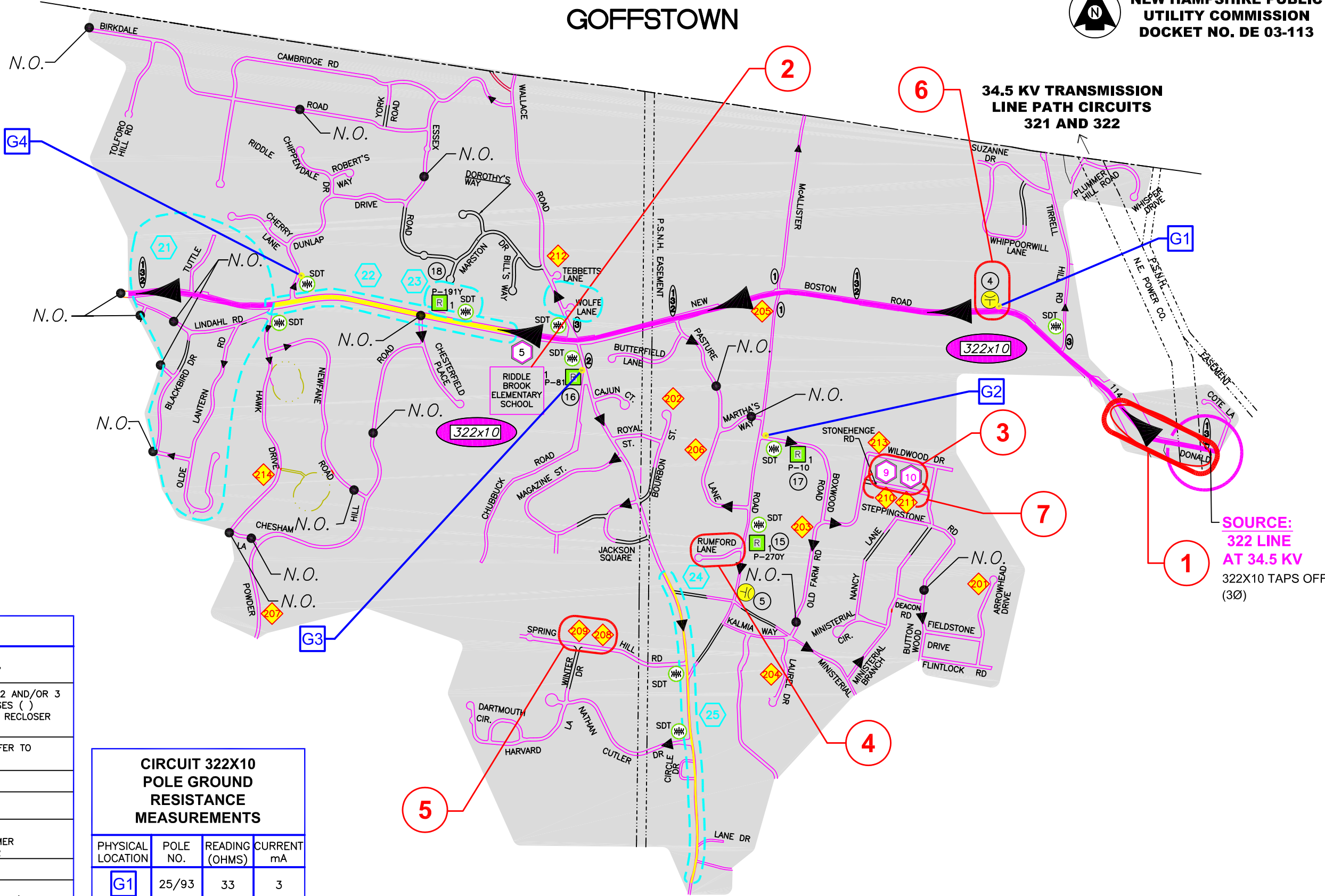
- A) DH PROVIDED PSNH WITH TWO, 3-PHASE (3 ϕ) 'MEGGER PA-9 PLUS' MONITORS FOR INSTALLATION BY PSNH.
- B) PSNH AND DH COORDINATED TIME CLOCK SETTINGS ON ALL MONITORS TO PERMIT COMPARISON OF RESULTS.
- C) PSNH CALIBRATED ALL MONITORS TO READ AND RECORD ALL INSTANTANEOUS EVENTS. HARMONICS READINGS WERE NOT REQUIRED.
- D) DH RECORDED EVENTS AT TWO, 3-PHASE (3 ϕ) LOCATIONS.
- E) PSNH RECORDED AT TWO, 3-PHASE (3 ϕ) LOCATIONS AND THREE, 1-PHASE (1 ϕ) LOCATIONS.
- F) SEE TABLE FOR POLE GROUND RESISTANCE MEASUREMENTS (G1 - G4).



FIGURE 7.2A



GOFFSTOWN



EQUIPMENT LEGEND	
	CAPACITOR BANK AND NUMBER. REFER TO 'CAPACITOR BANK SCHEDULE'
	RECLOSER AND NUMBER. NUMBERS 1, 2 AND/OR 3 DENOTE PHASE. NUMBER IN PARENTHESES () DENOTES QUANTITY. REFER TO '5 YEAR RECLOSER ACTIVITY SCHEDULE'.
	VOLTAGE REGULATOR AND NUMBER. REFER TO 'VOLTAGE REGULATOR SCHEDULE'.
	DIRECTION OF FLOW
	SUBSTATION
	TRANSFORMER: 'SDT' DENOTES STEP-DOWN TRANSFORMER 'SUT' DENOTES STEP-UP TRANSFORMER
	N.O. NORMALLY OPEN TIE POINT
	LOCATION OF CUSTOMER CONCERN REFER TO 'CUSTOMER CONCERN SCHEDULE'
	DENOTES LINE PHASE OR PHASES
	CIRCUIT UPGRADE/TRANSFER. REFER TO 'CIRCUIT UPGRADE/TRANSFER SCHEDULE'.

CIRCUIT 322X10 POLE GROUND RESISTANCE MEASUREMENTS			
PHYSICAL LOCATION	POLE NO.	READING (OHMS)	CURRENT mA
G1	25/93	33	3
G2	11/10Y	14	2
G3	2/81	20	0
G4	120/1	24	2

CIRCUIT 322X10
MONITORING PROGRAM MAP
CONDUCTED JULY 9 TO JULY 15, 2004

- Ground resistance was tested at the test metering locations and capacitor banks and regulators were disconnected per the testing schedule. Additional testing at two locations on Stonehenge Road involved installing an additional ground rod to determine the effect on ground resistance.

7.2.1 DONALD STREET NEAR TAP FROM 322 LINE

7.2.1.1 DH PA-9Plus Power Analyzer

The meter was installed on Donald Street pole 25/57Y and connected to a 480Y/277 volt transformer bank. The voltage leads measured a nominal 277 volts phase to neutral on each of the three phases. The NHPUC limits for this voltage is 254 volts minimum, 277 volts nominal and 288 volts maximum. The measurements are tabulated below, along with calculations to permit comparison with an equivalent 120 volt basis.



The recorded voltage was found to be on the high side of nominal and the maximum voltage recorded on Phase A was 290.7 volts which exceeded the NHPUC limit by 2.7 volts (0.9 volts on 120 volt base). Upon further analysis, this was found to be a single overvoltage event captured during the entire six day monitoring period as shown on Figure 7.2.1.1.

TABLE 7.2.1.1
DH PA-9PLUS POWER ANALYZER AT DONALD STREET

RECORDING PERIOD	START	7/9/04	12:07 PM	
	STOP	7/15/04	8:36 AM	
		Minimum Volts	Average Volts	Maximum Volts
Measured on 277 Volt Base	NHPUC Limit	254	277	288
	Phase A	271.9	281.8	290.7 Over
	Phase B	273.6	283.3	288.3
	Phase C	272.3	282.5	288.0

Same Data Calculated on 120 Volt Base for Comparison	NHPUC Limit	110	120	125
	Phase A	117.8	122.1	125.9 Over
	Phase B	118.5	122.7	124.9
	Phase C	118.0	122.4	124.8

FIGURE 7.2.1.1 Donald Street Voltage Recording During Test Showing One Overvoltage Event on Phase A

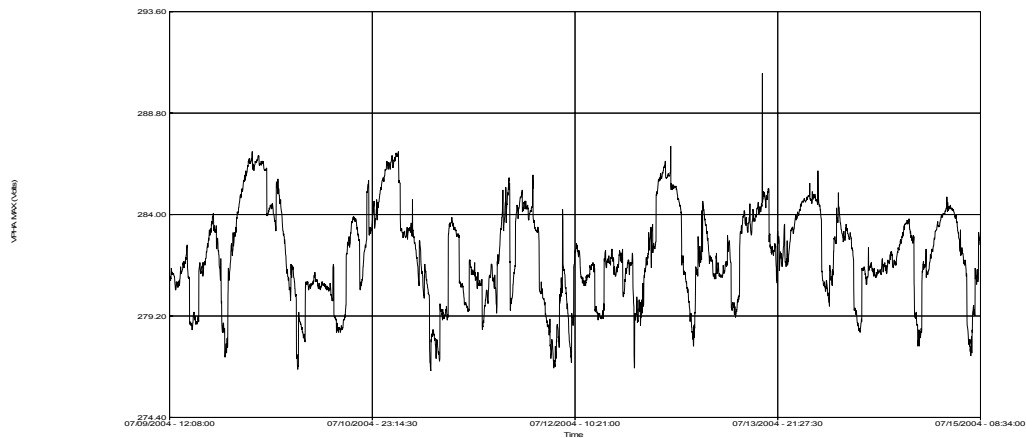
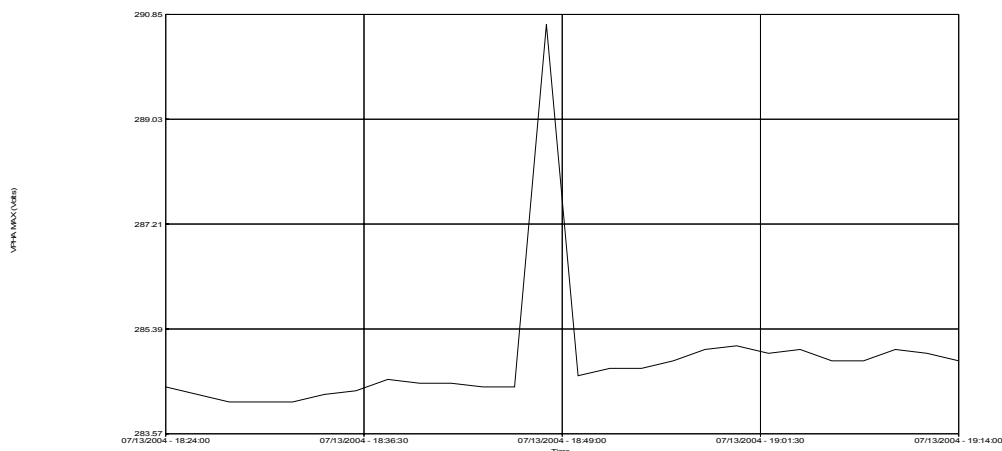


Figure 7.2.1.1 shows the voltage variation during the entire recording period and the voltage typically varies as expected. The voltage remained within the NHPUC voltage limits, except for a single overvoltage event that occurred on July 13, 2004 at 6:48 PM was recorded as 290.7 volts.

FIGURE 7.2.1.2 Donald Street Voltage Recording During Test Showing Detail of Overvoltage Event on Phase A



This event is magnified in Figure 7.2.1.2 which shows an overall time duration of four minutes from start to finish, but only about two minutes above the 288 volt limit. The meter was set to capture voltage measurements for each cycle and record the values on a two minute interval. Our monitoring confirms that the voltage on this circuit was maintained within NHPUC limits for the entire duration of the monitoring period.

7.2.1.2 PSNH PMI Monitor

The PSNH PMI meter was installed on the same pole 25/57Y as the DH and set to scan and capture every 17 milliseconds, or one cycle of the 60 Hz waveform. Table 7.2.1.2A shows the number of cycles spent at each voltage level during 7/8-7/15 monitoring period.

**TABLE 7.2.1.2A
DONALD STREET**

VOLTAGE	PH1	PH2	PH3
272	3	0	0
273	2923	0	960

VOLTAGE	PH1	PH2	PH3
274	7436	6	4886
275	10185	2061	7566
276	19946	7910	17186
277	116453	10991	126800
278	693331	29201	689747
279	1893851	257783	1625918
280	2816767	946406	2824975
281	4228301	2188163	3384987
282	5925896	3185538	6606849
283	4140462	5015788	4074535
284	4311576	5399580	4528750
285	3273149	5068162	3742425
286	2016724	4647093	1754009
287	1510996	2455610	1455582
288	68666	1751341	191209
289	148	70450	447
290	0	753	2
291	0	0	3
292	0	0	0

The table shows that some voltages were above the 288 volt NHPUC voltage limit, but not necessarily outside the five minute window. For example the 290 volt window captured 753 cycles on Phase B, which is equivalent to about 13 seconds total. The 289 volt window captured 70,450 cycles on Phase B, which is equivalent to about 19.6 minutes over the six day monitoring period. We requested additional information to determine the duration of these individual cycles at the 289 volt level and this is shown in Table 7.2.1.2C.

A weighted average of the one cycle voltage distribution in Table 7.2.1.2A is summarized in the following table:

TABLE 7.2.1.2B
PSNH PMI MONITOR AT DONALD STREET

		MINIMUM VOLTS	AVERAGE VOLTS	MAXIMUM VOLTS
Measured on 277 Volt Base	NHPUC Limit	254	277	288
	Phase A	272	282.6	289 Over
	Phase B	274	284.2	290 Over
	Phase C	273	282.7	291 Over
Calculated on 120 Volt Base for Comparison	NHPUC Limit	110	120	125
	Phase A	117.8	122.4	125.2 Over
	Phase B	118.7	123.1	125.6 Over
	Phase C	118.3	122.5	126.1 Over

The one cycle measurements exceed the voltage limits, but do not indicate if they exceeded the five minute allowable duration.

We attribute the differences in the maximum voltages between this table and Table 7.2.1.1 as differences in the meter time windows used to record the voltages between the two meters. Additional analysis of the voltage on a one minute basis appears to indicate that the voltage readings at 289 volts were of durations shorter than one minute.

PSNH provided a breakdown on a minute by minute basis and an excerpt is shown in Table 7.2.1.2C that indicates the maximum voltage was 288 volts on Phase B. Only a portion of this information is shown as the voltages were consistent throughout the entire data set and only the time values changed.

TABLE 7.2.1.2C

DONALD ST LIST OF THE HIGHEST 245 MINUTES OF VOLTAGE 7/13/04

DATE	TIME	CHANNEL 1	CHANNEL 2	CHANNEL 3
		Avg	Avg	Avg
07/13/2004	0:58:00	287	288	286
07/13/2004	0:59:00	287	288	287
07/13/2004	1:00:00	287	288	287
07/13/2004	1:01:00	287	288	287
07/13/2004	1:02:00	287	288	287
07/13/2004	1:07:00	287	288	287
07/13/2004	1:08:00	287	288	287
07/13/2004	1:09:00	287	288	287
07/13/2004	1:10:00	287	288	287
07/13/2004	1:11:00	287	288	287
07/13/2004	1:12:00	287	288	287
07/13/2004	1:13:00	287	288	287
07/13/2004	1:14:00	287	288	287
07/13/2004	1:15:00	287	288	287
07/13/2004	1:16:00	287	288	287
07/13/2004	1:17:00	287	288	287
07/13/2004	1:18:00	287	288	287
07/13/2004	1:19:00	287	288	287
07/13/2004	1:20:00	287	288	287
07/13/2004	1:21:00	287	288	287
07/13/2004	1:22:00	287	288	287
07/13/2004	1:23:00	287	288	287
07/13/2004	1:24:00	287	288	287
07/13/2004	1:25:00	287	288	287

The highest one minute average voltage on this day was recorded on phase B at 288v (104% of nominal), the NHPUC upper limit. This was the average for 199 minutes during the evening hours of 7/13/04

This data does not indicate any voltage above the permitted limit on a calculated one minute average. We interpret this to indicate that the individual cycles shown in Table 7.2.1.2A were very short duration and did not affect the one minute averages shown in Table 7.2.1.2C. It does indicate that the system frequently operates at the high end of the NHPUC voltage limit.

The voltage measurement at Donald Street remained within NHPUC limits for the entire duration of the monitoring period.

7.2.1.3 Ground Resistance

The ground resistance at pole 25/57Y on Donald Street was 35.2 ohms with a ground current of 3 mA at the time of meter installation.

7.2.2 RIDDLE BROOK ELEMENTARY SCHOOL, NEW BOSTON ROAD

7.2.2.1 DH PA-9Plus Power Analyzer

The meter was installed inside the 480Y/277 volt pad-mounted transformer cabinet. The voltage leads measured a nominal 277 volts phase to neutral on each of the three phases. The NHPUC limits for this voltage is 254 volts minimum, 277 volts nominal and 288 volts maximum. The measurements are tabulated below, along with calculations to permit comparison with an equivalent 120 volt basis.



The recorded voltage was found to be on the high side of nominal and the maximum recorded voltage on phase C exceeded the NHPUC limit by almost 1.5 volts and required further analysis.

TABLE 7.2.2.1
DH PA-9PLUS POWER ANALYZER AT RIDDLE BROOK ELEMENTARY
SCHOOL

RECORDING PERIOD	START	7/9/04	9:58 AM	
	STOP	7/15/04	9:11 AM	
		Minimum Volts	Average Volts	Maximum Volts
Measured on 277 Volt Base	NHPUC Limit	254	277	288
	Phase A	276.0	282.5	287.4
	Phase B	276.1	282.0	287.5
	Phase C	276.7	282.3	289.4 Over

Calculated on 120 Volt base for Comparison	NHPUC Limit	110	120	125
	Phase A	119.6	122.4	124.5
	Phase B	119.6	122.2	124.5
	Phase C	119.9	122.3	125.4 Over

FIGURE 7.2.2.1 Riddle Brook School Voltage Recording During Test Showing Overvoltage Event on Phase C

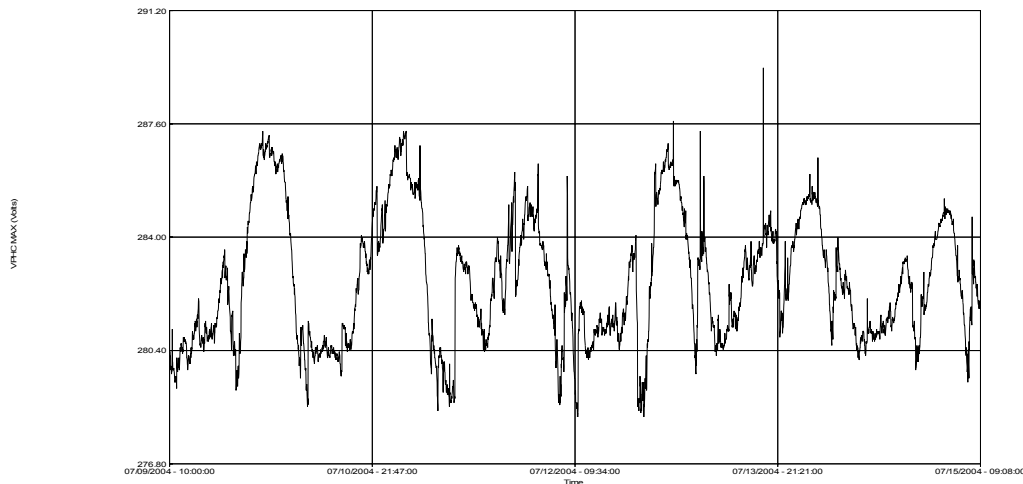
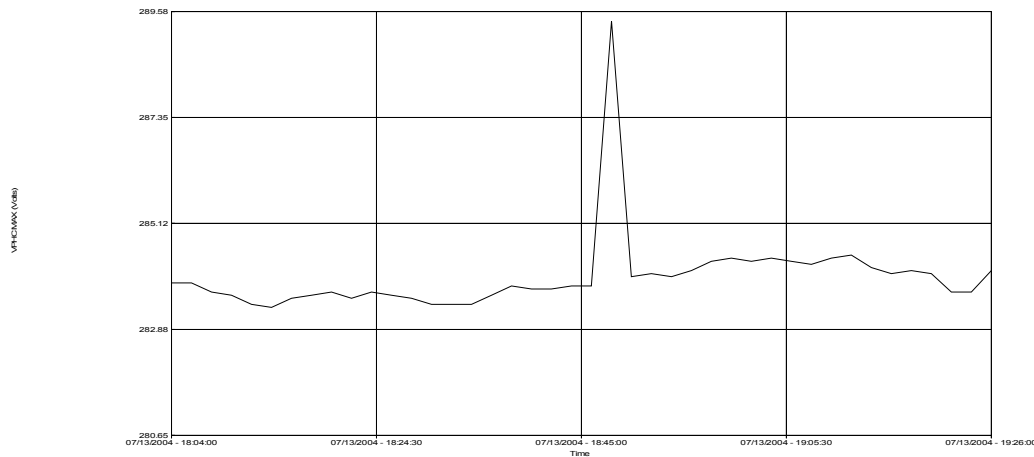


Figure 7.2.2.1 shows the voltage variation during the recording period and the voltage varies as expected. There is a single overvoltage event that occurred on July 13, 2004 at 6:48 PM that was recorded as 289.4 volts. This event was the same one recorded at Donald Street at the same time and is magnified in Figure 7.2.2.2.

The apparent discrepancy of this event recorded on Phase A at Donald Street and Phase C at Riddle Brook is the result of independent meter connections at both locations without attempting to match phase wire connections between monitoring locations. This event was captured on only one phase at both locations and the discussion under Donald Street is applicable here for the same event.

FIGURE 7.2.2.2 Riddle Brook School Voltage Recording During Test Showing Detail of Impulse on Phase C



This event is magnified in Figure 7.2.2.2 which shows an overall time duration of four minutes from start to finish, but only about two minutes above the 288 volt limit. The meter was set to capture voltage measurements for each cycle and record the values on a two minute interval. Our monitoring confirms that the voltage on this circuit was maintained within NHPUC limits for the entire duration of the monitoring period.

The voltage measurement at Riddle Brook School remained within NHPUC limits for the entire duration of the monitoring period.

7.2.2.2 PSNH PMI Monitor

The existing PMI monitor inside the pad-mounted transformer cabinet was reprogrammed. PSNH was unable to provide this information for inclusion in the report due to a software problem. We are satisfied with DH monitoring results for this location since they parallel the data from Donald Street.

7.2.2.3 Ground Resistance

The ground resistance at the transformer was 0.07 ohms with a ground current of 2.022 Amps.

7.2.3 STONEHENGE ROAD

7.2.3.1 PSNH PMI Monitor

The PMI monitor was installed on the top of pole 314/4.

Stonehenge pole mount - Number of cycles spent at each voltage level during 7/8 – 7/15 monitoring period.



TABLE 7.2.3.1A
STONEHENGE ROAD

VOLTAGE	PH1	PH2
116	0	0
117	17	0
118	36295	66727
119	3529086	4650674
120	11467797	11506913
121	8555466	7989943
122	5397666	5354533
123	2114371	1531919
124	1	0
125	0	0

A weighted average of the voltage distribution is summarized in the following table:

TABLE 7.2.3.1B
PSNH PMI MONITOR AT STONEHENGE ROAD

	MINIMUM VOLTS	AVERAGE VOLTS	MAXIMUM VOLTS
NHPUC Limit	110	120	125
Phase A	117	120.7	124
Phase B	118	120.6	123

7.2.3.2 Ground Resistance Tests

We witnessed PSNH perform two ground resistance tests to determine the effect of an additional ground at a pole. The tests were conducted in soil that was moist following periods of rain on the previous day.

- Test #1 - The ground resistance on the existing #4 copper ground at pole 314/4 was 8.0 ohms with a ground current of 10 mA.

A second ground rod was located approximately 8 feet from the existing pole ground and driven until hitting ledge at a depth of 3 feet. The new ground resistance was measured as 0.95 ohms with a ground current of 12 mA. When the second ground rod was removed, the original ground measured 7.7 ohms with a ground current of 17 mA.

Result - Test #1 demonstrated that the ground resistance at a pole could be reduced by the installation of multiple ground rods.

- Test #2 - The ground resistance on the existing ground at pole 314/3 was 3.6 ohms with a ground current of 1 mA.

A second ground rod was located approximately 8 feet from the existing pole ground and driven until hitting ledge at a depth of 3 feet. The new ground resistance was measured as 129 ohms with a ground current of 1 mA. When the second ground rod was removed, the original ground measured 24.7 ohms with a ground current of 12 mA. A loose connection on the original ground was tightened and the original ground now measured 51.5 ohms with a ground current of 1 mA.

Result - Test #2 was inconclusive as the resistance readings increased when we would have expected a decrease. The cause of the high resistance was not determined, but could be caused by loose contact between the ground rods and soil.

Multiple ground rods could be used to reduce the ground resistance, if required, at isolated locations. We have no specific recommendations as this was primarily a test to determine the effect of installing an additional ground rod to augment an existing rod. The divergence

between the two tests shows the importance of proper installation and testing in such applications.

7.2.4 RUMFORD LANE

7.2.4.1 PSNH PMI Voltage Monitor

PSNH installed a PMI Voltage Monitor inside pad-mounted transformer T1.

Table 7.2.1.2A shows the number of cycles spent at each voltage level during 7/8-7/15 monitoring period.

TABLE 7.2.4.1A
RUMFORD LANE

VOLTAGE	PH1	PH2
116	0	0
117	0	33
118	44	499
119	130445	1119997
120	5037916	8268604
121	12145016	10938834
122	7974552	6981356
123	5006771	3565662
124	584704	4475
125	1	0
126	0	0

A weighted average of the voltage distribution is summarized in the following table:

TABLE 7.2.4.1B
PSNH PMI MONITOR AT RUMFORD LANE

	MINIMUM VOLTS	AVERAGE VOLTS	MAXIMUM VOLTS
NHPUC Limit	110	120	125
Phase A	118	121.5	125
Phase B	117	121.1	124

7.2.4.2 Ground Resistance

The ground resistance at transformer T1 was 0.03 ohms with a ground current of 178 mA at the time of meter installation. The soil was moist from recent rain.

7.2.5 SPRING HILL ROAD

7.2.5.1 PSNH RPM Voltage Monitor

PSNH installed a high speed RPM Voltage Monitor inside pad-mounted transformer T2.

FIGURE 7.2.5.1A Spring Hill Phase A during the 7/12 cap switching on pole 25/93 New Boston Road and during the 7/13 cap switching on pole 25/93 New Boston Road

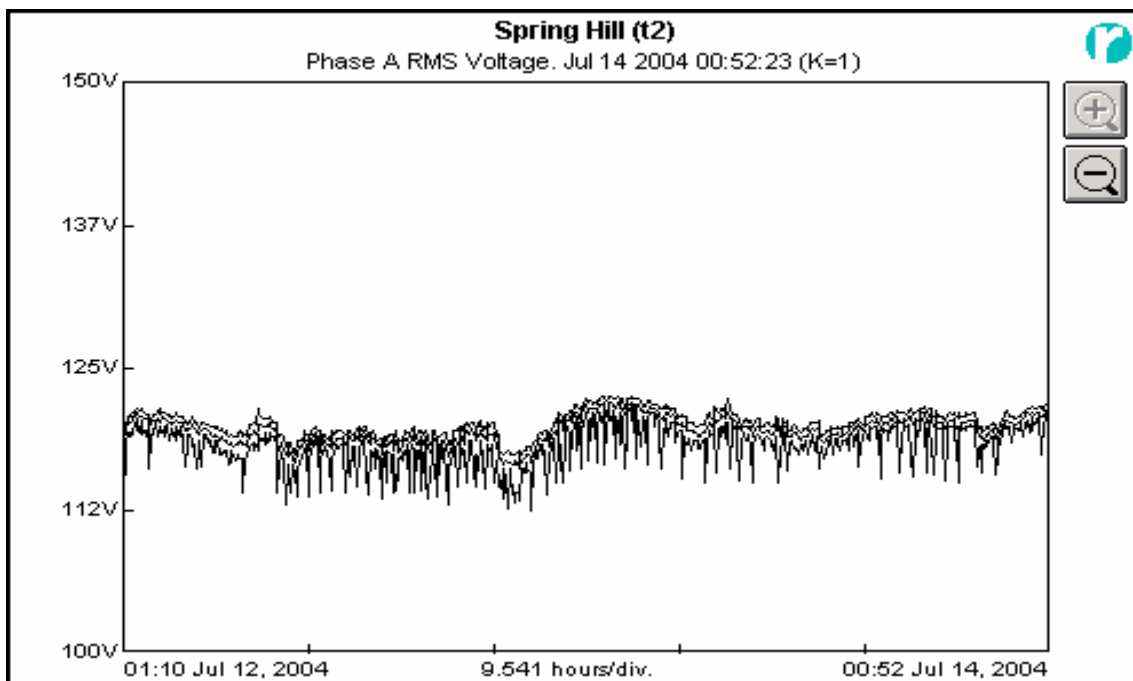
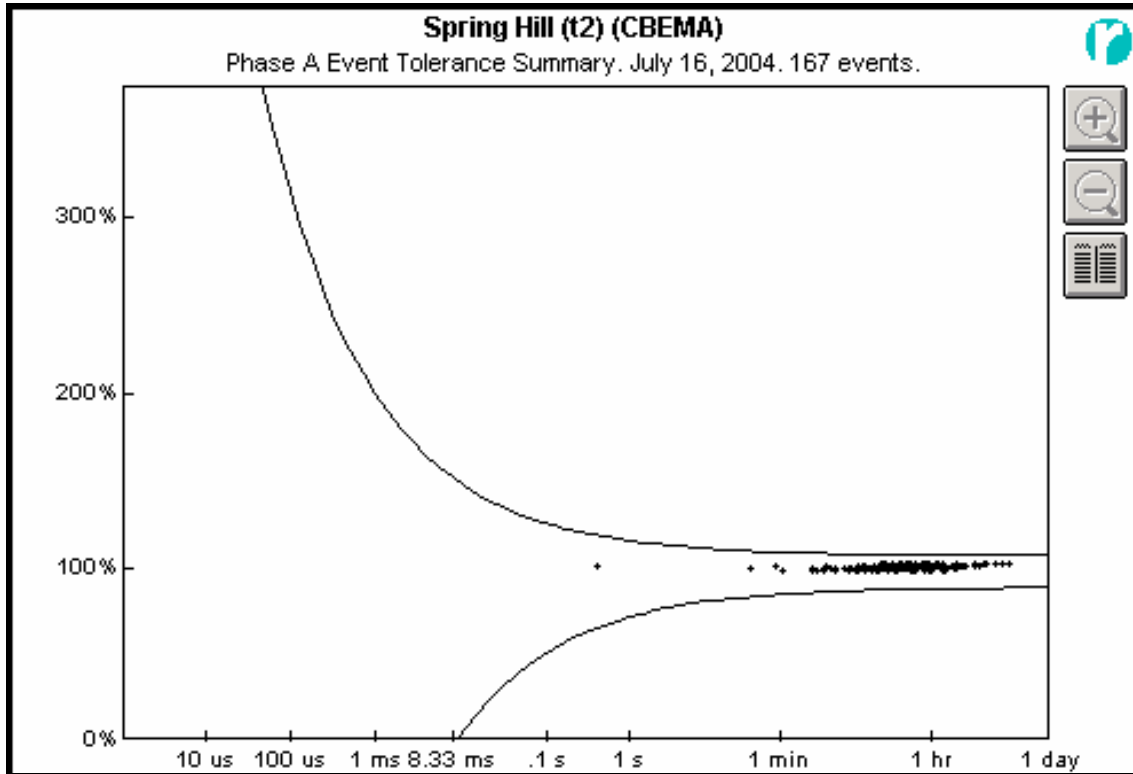


FIGURE 7.2.5.1B Spring Hill Phase A&B voltage events vs CBEMA curve during the 7/12 cap switching on pole 25/93 New Boston Road and during the 7/13 cap switching on pole 25/93 New Boston Road



7.2.5.2 Ground Resistance

The ground resistance at transformer T2 was 0.18 ohms with a ground current of 111 mA. The soil was moist from recent rain.

7.3 SUMMARY OF CIRCUIT 322X10

Based on the results detailed above, the following conclusion can be made:

F8 The voltage on the 322X10 circuit remained within NHPUC limits during the monitoring period.

SECTION 8

CUSTOMER MONITORING RESULTS

8.1 OVERVIEW

This section covers limited monitoring conducted within the customer's system after the electric meter. The NHPUC voltage limits apply only to the electric meter and voltage within the customer systems may be less due to local voltage drops within the branch circuit wiring.

This was not designed to be a comprehensive study since it consisted of only one location on each of the two primary feeders. The intent was to investigate the types of interaction between utilization equipment and electrical service. Each customer is different. Existing systems may have been expanded, central air conditioning may have been installed, the electrical work may have been done by individuals with different skill levels, or a number of other factors may be involved.

Monitoring was performed in public buildings to avoid any appearance of favoritism or conflict of interest. While these are not residences, they are representative of changing electrical load conditions and demonstrate the utilization equipment impacts on the utility system voltage.

8.2 BEDFORD TOWN HALL - CIRCUIT 3W2

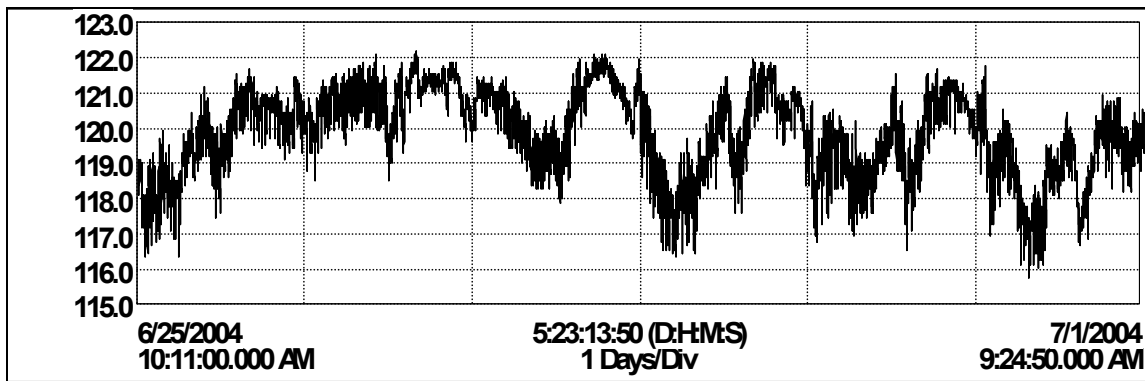
The Town Hall is used on a daily basis and has a definite occupancy schedule that involves different types of electrically operated equipment, such as motors, office equipment, lighting and miscellaneous loads. DH installed an AEMC PQL120 Power Quality Logger and a Cutler-Hammer Power Watch PW-200 voltage event logger in a storage room to record voltage conditions inside the building.



8.2.1 DH AEMC PQL-120 POWER LOGGER

The average branch circuit voltage recorded in the town hall ranged from 115.7 to 122.0 Volts, as shown on the voltage graphs. A single maximum voltage of 123.4 volts was recorded and several voltage sags dipped below 108 volts.

FIGURE 8.2.1.1 RMS Voltage Recorded Inside the Town Hall



The frequent voltage sags recorded in the town hall were observed by the PA-9Plus pole mounted meter, but not to the same degree as measured in the building. This indicates that the apparent cause is located within the building.

FIGURE 8.2.1.2 RMS Minimum Voltage Recorded Inside the Town Hall showing Voltage Sags

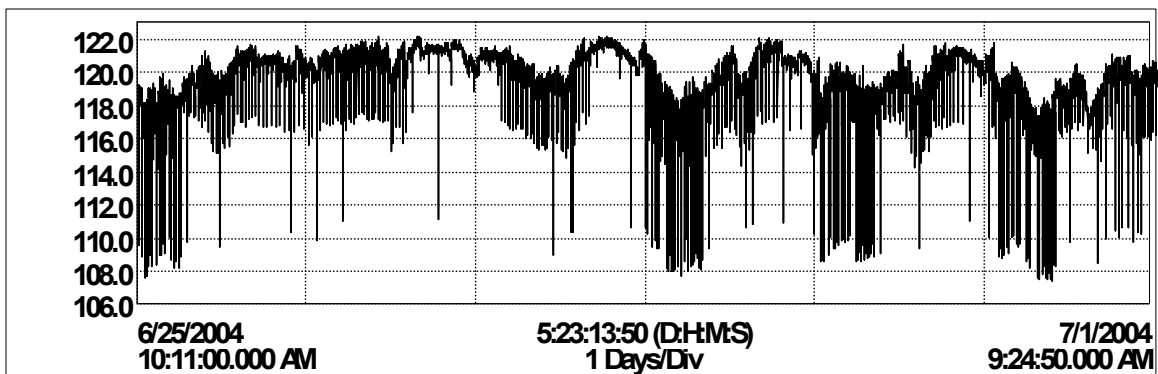
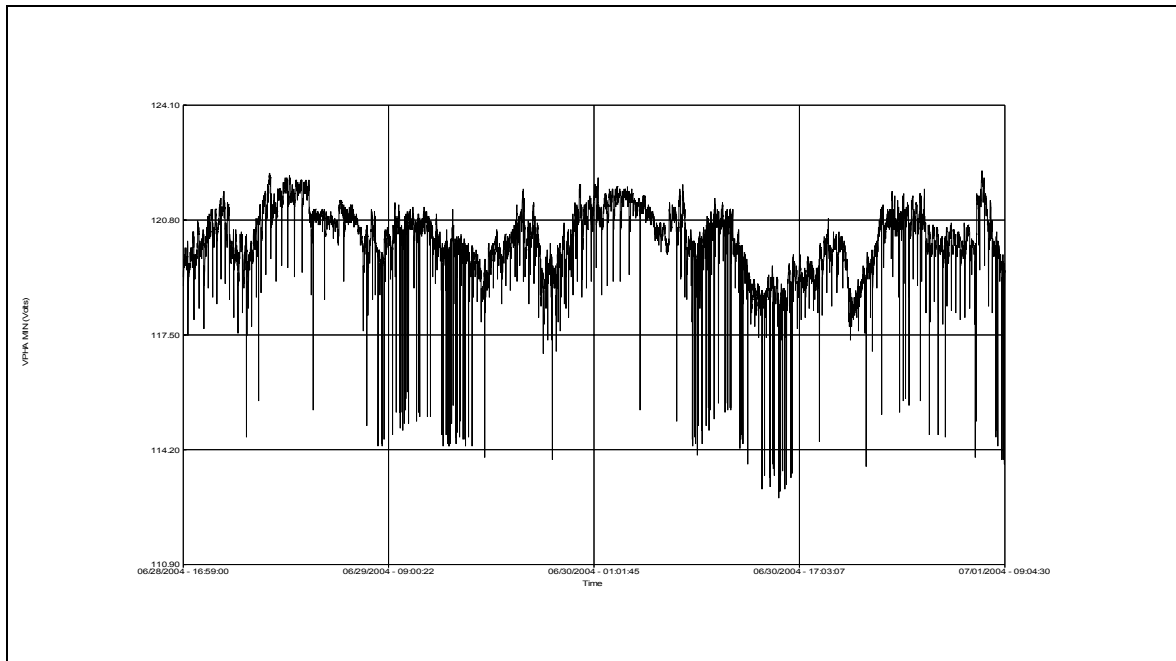


FIGURE 8.2.1.3 Phase A RMS Minimum Voltage Recorded on Pole showing Voltage Sags at Utility Transformer Secondary Terminals



These two graphs indicate that the voltage sags caused by equipment inside the Town Hall impact the transformer serving the building. If other customers were connected to this transformer, they would also be affected by the voltage sags. The transformer provides a fair degree of isolation so these sags have little impact on the primary line voltage.

8.2.2 DH CUTLER HAMMER PW200 POWER WATCH EVENT LOGGER

The events, recorded primarily during working hours between 8:00 AM and 4:30 PM, indicate numerous voltage sag events typically in the range of 107 to 109 volts and of very short duration, typically 3 to 4 cycles. These observations usually represent items such as the starting of equipment such as a photocopier heater or drive motor, an air conditioner, well pump or similar item. Our goal was not to identify individual causes, only the net effect on utilization voltage.

The PSNH voltage sag graphs in Section 7 illustrate this effect as a number of vertical lines extending below the typical voltage variations on the graph.

These voltage levels are in general agreement with the AEMC meter data.

TABLE 8.2.2.1

EXCERPT OF VOLTAGE SAG EVENTS RECORDED IN THE TOWN HALL

DATE	START TIME	EVENT	EXTREME VALUE	DURATION
6/28/2004	4:41:20 PM	H-N Sag	108 Volts RMS	3.0 cycles
6/28/2004	3:56:00 PM	H-N Sag	108 Volts RMS	3.0 cycles
6/28/2004	3:52:16 PM	H-N Sag	108 Volts RMS	3.5 cycles
6/28/2004	3:51:04 PM	H-N Sag	108 Volts RMS	3.0 cycles
6/28/2004	3:41:12 PM	H-N Sag	107 Volts RMS	3.5 cycles
6/28/2004	3:40:16 PM	H-N Sag	107 Volts RMS	3.5 cycles
6/28/2004	3:36:08 PM	H-N Sag	108 Volts RMS	3.0 cycles
6/28/2004	3:34:24 PM	H-N Sag	108 Volts RMS	3.0 cycles
6/28/2004	3:26:48 PM	H-N Sag	108 Volts RMS	3.5 cycles
6/28/2004	3:22:24 PM	H-N Sag	108 Volts RMS	3.5 cycles
6/28/2004	3:06:40 PM	H-N Sag	107 Volts RMS	3.0 cycles
6/28/2004	2:57:44 PM	H-N Sag	108 Volts RMS	3.5 cycles
6/28/2004	2:50:40 PM	H-N Sag	107 Volts RMS	3.5 cycles
6/28/2004	2:42:32 PM	H-N Sag	108 Volts RMS	3.5 cycles
6/28/2004	2:29:44 PM	H-N Sag	107 Volts RMS	3.5 cycles
6/28/2004	2:18:24 PM	H-N Sag	108 Volts RMS	3.5 cycles
6/28/2004	1:53:52 PM	H-N Sag	108 Volts RMS	3.5 cycles
6/28/2004	1:50:40 PM	H-N Sag	107 Volts RMS	3.5 cycles
6/28/2004	1:34:00 PM	H-N Sag	109 Volts RMS	3.0 cycles
6/28/2004	1:19:44 PM	H-N Sag	108 Volts RMS	3.0 cycles
6/28/2004	1:00:40 PM	H-N Sag	107 Volts RMS	3.5 cycles
6/28/2004	12:58:40 PM	H-N Sag	106 Volts RMS	4.0 cycles
6/28/2004	12:29:12 PM	H-N Sag	106 Volts RMS	4.0 cycles
6/28/2004	12:10:00 PM	H-N Sag	107 Volts RMS	4.0 cycles
6/28/2004	12:00:40 PM	H-N Sag	107 Volts RMS	3.5 cycles
6/28/2004	11:57:52 AM	H-N Sag	107 Volts RMS	3.5 cycles
6/28/2004	11:51:52 AM	H-N Sag	107 Volts RMS	3.5 cycles
6/28/2004	11:40:16 AM	H-N Sag	106 Volts RMS	4.0 cycles
6/28/2004	11:32:24 AM	H-N Sag	108 Volts RMS	3.5 cycles
6/28/2004	11:30:16 AM	H-N Sag	108 Volts RMS	3.0 cycles
6/28/2004	11:29:20 AM	H-N Sag	108 Volts RMS	3.0 cycles
6/28/2004	11:18:00 AM	H-N Sag	108 Volts RMS	3.5 cycles
6/28/2004	11:11:20 AM	H-N Sag	106 Volts RMS	3.5 cycles
6/28/2004	11:06:40 AM	H-N Sag	108 Volts RMS	3.5 cycles
6/28/2004	11:05:04 AM	H-N Sag	109 Volts RMS	3.0 cycles
6/28/2004	10:54:00 AM	H-N Sag	107 Volts RMS	3.0 cycles
6/28/2004	9:46:24 AM	H-N Sag	108 Volts RMS	3.0 cycles

This instrument also recorded instantaneous impulse events associated with capacitor switching on the utility system. One example is shown in this Section with the maximum instantaneous voltages resulting from Capacitor 15 on pole 9/29 switching on at 8:00 AM.

FIGURE 8.2.2.1 Switching Transient Caused by Capacitor Switching On – Negative Impulse

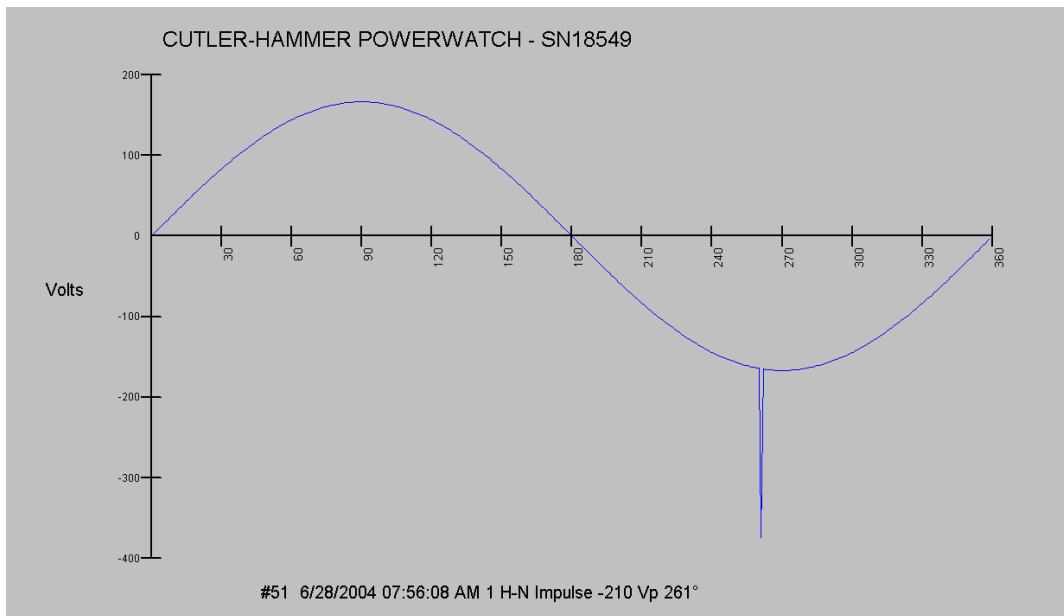
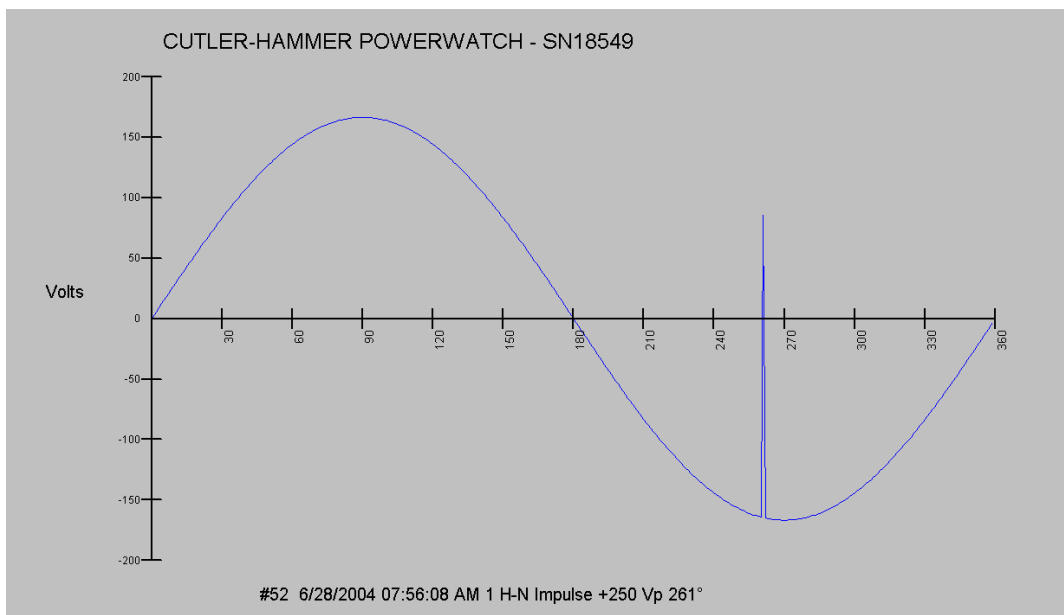
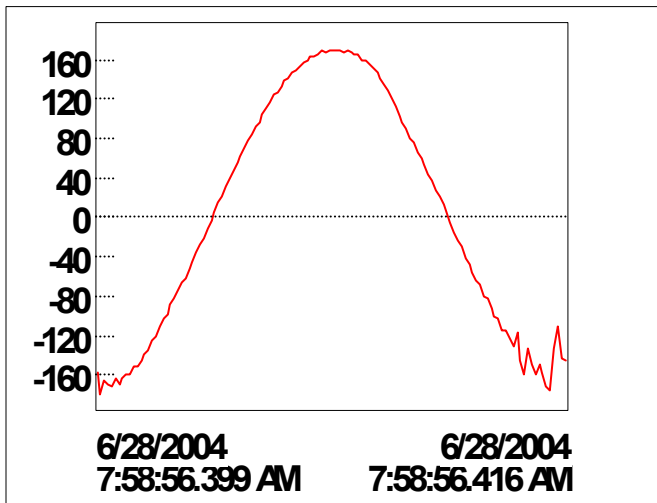


FIGURE 8.2.2.2 Switching Transient Caused by Capacitor Switching On – Positive Impulse



This is a typical waveform. These transients were also observed by the other meters; however the magnitudes of the impulses were not as great due to differences in meter characteristics. The waveform for this impulse was captured on the AEMC meter and the waveform distortion shown is typical. (The time recorded on this meter is slightly different as the meter clocks could not be synchronized.)

FIGURE 8.2.2.3 Same Switching Transient Captured on AEMC Meter



Impulses of this type are infrequent and we only found them when capacitors were switched on, but not every time of switching. The purpose of this illustration is to indicate that system disturbances may occur from time to time on the utility system. We did not find any unusual impulses or voltage spikes beyond capacitor switching.

8.2.3 SUMMARY

Voltage sags were measured inside the building and also observed by the meter on the pole. The sags were of very short duration and remained within the time frame of the NHPUC voltage limits. These instantaneous voltage dips have apparently existed in the past and we had no reports of any adverse impacts on building or office operations.

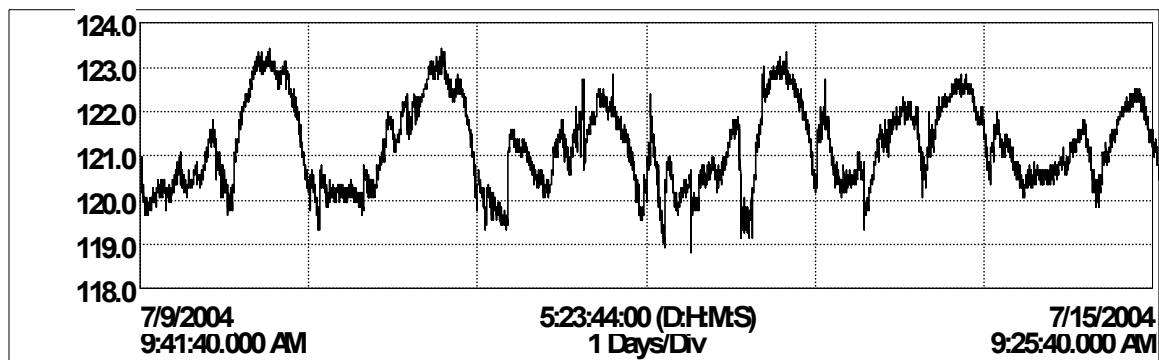
8.3 RIDDLE BROOK SCHOOL – CIRCUIT 322X10

Additional monitoring was performed inside the Riddle Brook Elementary School. This building is minimally used in the summer and was not expected to have as many voltage events as the Town Hall. DH installed an AEMC PQL120 Power Quality Logger and a Cutler-Hammer Power Watch PW-200 voltage event logger in a closet to record voltage conditions inside the building.

8.3.1 DH AEMC PQL-120 POWER LOGGER

The average branch circuit voltage recorded in the school ranged from 118.8 to 123.3 Volts, as shown on the voltage graphs. A single maximum voltage of 123.6 volts was recorded and the worst voltage sag dipped to 117.9 volts.

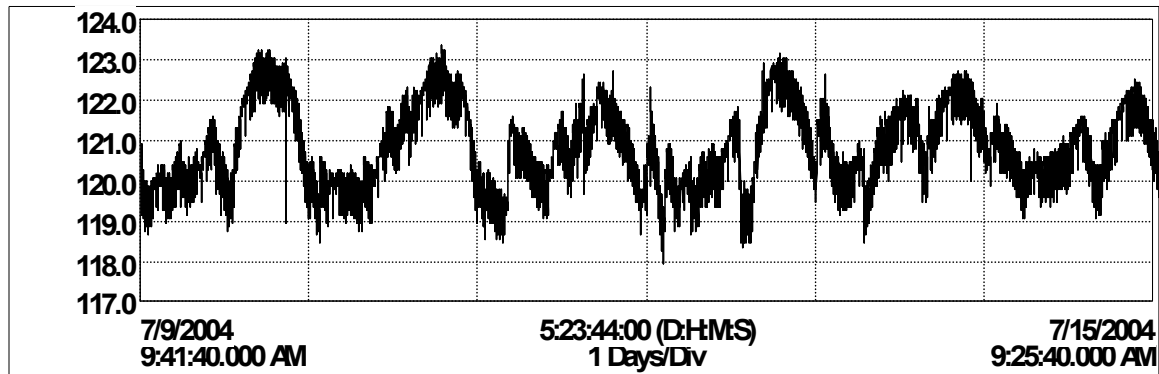
FIGURE 8.3.1.1 RMS Voltage Recorded Inside the Riddle Brook School



The highest voltage reading is approximately equivalent to the data above and would be expected during periods of light load in the building. Note that the width of the line is narrower than that on some other graphs and indicates very little short term voltage variation.

The lowest voltage is the voltage at the transformer minus losses in the service and internal building wiring. Voltage drops would be expected to increase during periods of heavier power use when the building is fully operational. The graph shows that most events are voltage sags, which may be caused by the inrush current when motorized equipment starts. In any case, the voltage remained within NHPUC limits.

FIGURE 8.3.1.2 RMS Minimum Voltage Recorded Inside the Riddle Brook School



In this case, the line width is wider than the previous and indicates numerous short term voltage variations but no significant sags, such as observed in the Town Hall.

8.3.2 DH CUTLER HAMMER PW200 POWER WATCH EVENT LOGGER

No events were recorded where the voltage deviated outside the NHPUC voltage limits.

8.3.3 SUMMARY

The utility power to this building was within NHPUC limits and there were no significant voltage sags or dips observed during the monitoring period. The internal voltage measurements paralleled that observed on the utility pole.

8.4 DISCUSSION OF METERING RESULTS

The two buildings studied showed totally different results, yet we understand that both buildings function without problems. If this limited analysis is extrapolated over a large number of customers, it is readily apparent that individual customer variations exist on the same utility system.

- The voltage measured inside one location indicated numerous voltage sags of very short duration.
- Problems experienced by one customer are not generally observed by another customer.

- Sags are often caused within the customer's system and beyond the utility's responsibility.
- Instantaneous sags do not necessarily cause problems with building operations
- Service voltage variations within the NHPUC limits are typical of normal electrical system operation.

SECTION 9

REPORT SUMMARY AND RECOMMENDATIONS

9.1 SUMMARY

The activities described in this report have attempted to show that the customer concerns are distributed throughout the town, list improvements have been made by PSNH and measure voltage variations on the system. Our attempt to provide additional insight toward continued resolution of these issues focused on utility and customer components of the power quality issue.

9.1.1 UTILITY POWER SYSTEM TO THE CUSTOMER METER

The utility voltage was monitored and the utility actions to solve power quality issues were reviewed in this report.

9.1.2 CUSTOMER ELECTRICAL SYSTEM BEYOND THE METER

Appendix A describes the basic grounding and service wiring configuration as an aid to understanding this portion of the electrical system. We found that customer equipment can cause voltage sags in some cases. This indicates that the utility may not be responsible for some customer power quality issues, but there is no current process for the utility to assist on the customer side of the meter.

This section describes a concept to address this concern.

9.1.3 ELECTRICALLY POWERED EQUIPMENT AND APPLIANCES

This scope of this report did not include any analysis of customer owned equipment failures; however some related commentary and discussion is included for information purposes.

9.2 CONCLUSIONS

We found the PSNH power distribution system in Bedford to be comparable to that of similar utilities, except for the large number of feeder circuits serving the town. The utility has a documented record of system maintenance activities and responsiveness to customer complaints. Not all reported problems have been resolved and additional actions will be required to meet this goal.

9.3 GENERAL OVERVIEW

Our conclusions thus far, have found that PSNH has attempted to respond to the various concerns and complaints with constructive responses. Individual transformers, services and facilities have been upgraded to resolve some complaints. It is now time to step back and look at this entire situation in a larger context.

The historic approach to voltage complaints has been based on the long standing assumption that the utility is responsible for the quality and adequacy of power under NHPUC requirements. The utility's responsibility extends only to the electric meter and they are not authorized to take any action beyond the meter.

New Hampshire state law does not prohibit the owner of a single family residence from making electrical installations in their own residence under RSA 319-C:15, II. For this reason, there may be considerable differences in the adequacy and code compliance of the electrical systems in individual residences. While some home owners use a licensed electrician for this work, the home handyman is not prohibited from installing his own equipment and installing the wiring.

It appears that in spite of ongoing efforts, the utility has not been able to resolve every reported problem. This leads us to conclude that perhaps the problem is inside the customer's system. To date, the separate and uncoordinated efforts by both utility and electricians, acting independently to resolve the problems have not been entirely successful.

Perhaps it is time to consider that a new coordinated effort is required to augment existing procedures and provide a mechanism to approach the more difficult problem areas that have been resistant to previous attempts at resolution.

9.4 POWER QUALITY IMPROVEMENT TEAM RECOMMENDATION

The present utility method of investigating customer complaints works well in determining problems on the utility distribution system but does not logically extend to problems that may be internal to the customer. Where such problems may exist, there is no present formal mechanism to evaluate power quality inside the customer's premises. Closing the loop on this could eliminate lingering problems and repeat complaints, as well as make strides toward improving customer relations with the utility.

A pilot program could be developed to combine resources of both the utility and licensed electrical contractors to investigate power quality issues simultaneously as a team. The basic program concept could include such tasks and responsibilities as:

9.4.1 CUSTOMER RESPONSIBILITIES

- Select a licensed electrician and pay related costs.
- Provide access to property.
- Participate to describe symptoms and answer questions from utility and electrician.
- Be responsible to correct any deficiencies found.

9.4.2 JOINT UTILITY AND ELECTRICIAN TASKS

- Meet simultaneously with the customer at the customer location.
- Assist each other in taking measurements and interpreting results.
- Explain findings and proposed actions to customer.
- Document the results of the investigation as a reference for future problem solving.
- Solve the problem in one visit.

9.4.3 UTILITY TASKS

- Provide an experienced power quality engineer on site to guide the process, provide technical direction and interpret the results as the process unfolds.
- Provide qualified personnel and equipment appropriate to the problem or complaint, including line truck for access to pole mounted equipment.
- Verify phase and neutral configuration at both transformer and meter.
- Verify the integrity of service phase and neutral wire connections at transformer and meter.
- Measure voltages from phase to phase and each phase to neutral at transformer.
- Measure phase and neutral currents at transformer.
- Measure ground resistance and ground current at transformer pad or pole.
- Correct any deficiencies found on the utility side of the meter.

9.4.4 ELECTRICIAN TASKS

- Provide qualified personnel and equipment on site.
- Verify phase and neutral connections at meter and electrical panel.
- Check the integrity of the service ground system.
- Measure ground resistance and ground current at electrical panel.
- Measure voltages from phase to phase and each phase to neutral.
- Measure phase and neutral currents.
- Check load balance between phases in electrical panel and rebalance if necessary.
- Check branch circuits for proper connections and grounding.

9.4.5 IMPLEMENTATION

- The details of such a pilot program are best left to the utility to develop.
- A checklist should be prepared to guide the field investigation in logical steps .
- The investigation should be performed quickly, competently and provide specific results to close the complaint in one meeting.

- The program should be closely monitored for effectiveness, under engineering supervision, and modified as required.
- Documentation of the diagnosis and corrective action should be developed as a guide for resolution of similar problems in the future.
- The results of each investigation should be forwarded to the NHPUC for program evaluation.

This is only a suggested outline of a program concept and it is open to further development and definition by the participants. In our opinion, this could be a viable option to the power quality questions that remain unsolved to date.

R5 Consider developing a Power Quality Team concept combining PSNH resources and licensed electricians to investigate situations that have resisted other attempts at resolution.

APPENDIX A

COMMENTARY ON GROUNDING SYSTEMS

APPENDIX A

COMMENTARY ON GROUNDING SYSTEMS

GROUNDING THEORY

The entire earth is considered to be a massive conductor with an assumed electrical potential of zero volts anywhere on its surface. When a metal conductor is inserted into the earth, it is considered grounded with an electrical potential of zero volts.

If a voltage is applied to the grounded conductor, current flows until the voltage between the metal conductor and the earth are equalized. No matter how much voltage is applied, it is not possible to change the earth's voltage from zero by any action mankind understands. If a lightning stroke hits a ground connection, a high current will flow until the lightning charge is equalized to the earth's potential. Grounding is a way to prevent a grounded object from assuming a potential that drastically differs from that of the earth.

The basic concept for grounding is to provide a common electrical reference for power systems by connection to the earth.

GROUNDING PRACTICE

Localized soil conductivity variations affect the ability of current to flow through the earth, and thus the effectiveness of individual connections to ground. Low resistance soils, or water, can pass high currents but high resistance soils limit the current that can be absorbed readily. An equivalent ground in high resistance soil will require multiple ground connections bonded together over a large area compared to a single ground connection in a low resistance area.

In practice, the earth is not used intentionally as a conductor between two separated ground connections, since a wire is a more efficient and lower resistance conductor. In an electrical distribution system, this conductor is called the neutral and it is typically grounded at

multiple locations along the circuit. The ground connections are made for the following safety reasons:

- To limit high voltage conditions caused by lightning or accidental contact with a higher voltage power conductor.
- To provide a voltage reference relative to earth.
- To provide a fault current path during system faults to permit the operation of protective devices.

In summary, grounding is for safety.

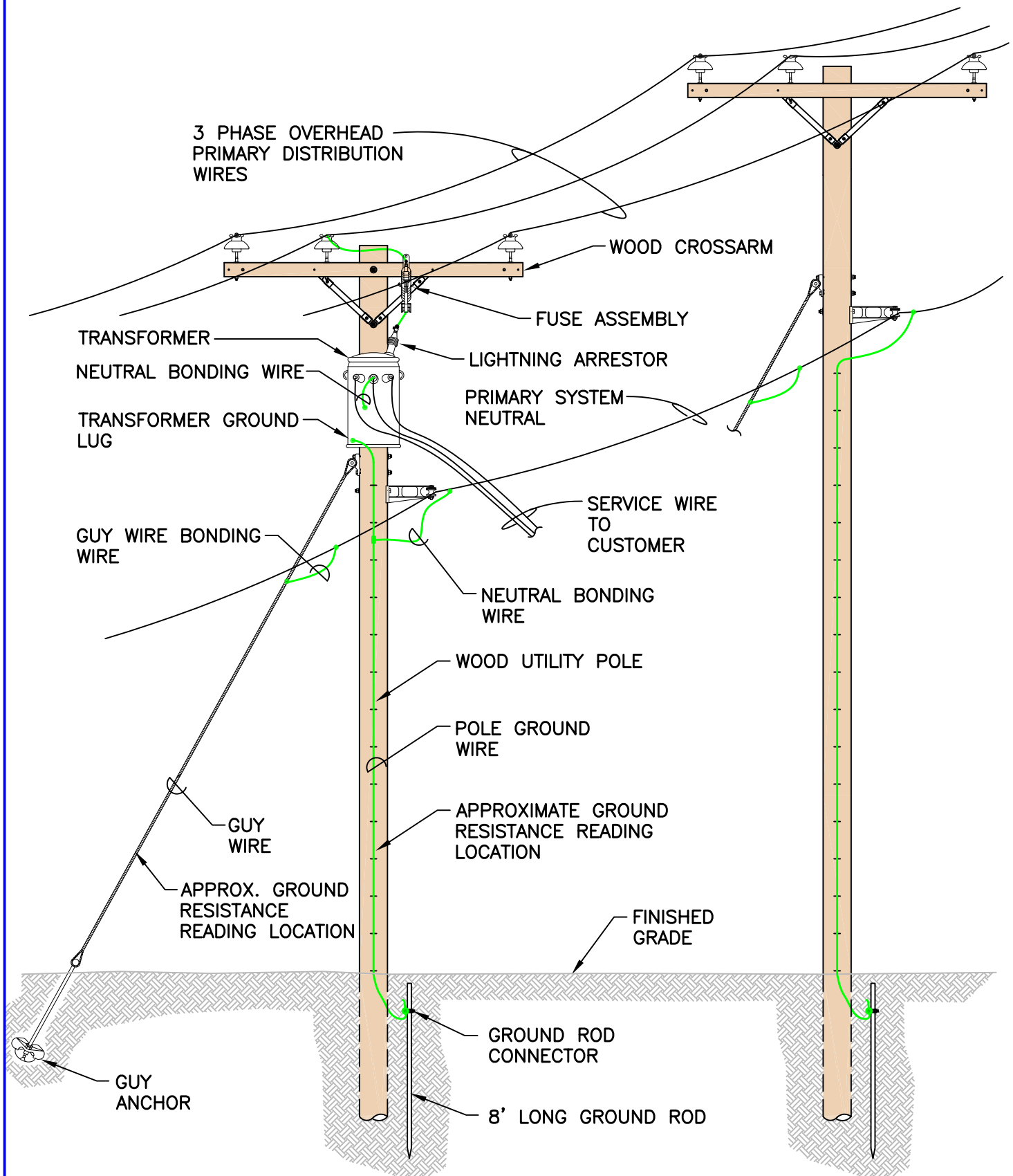
DESCRIPTION OF THE UTILITY GROUNDING SYSTEM

A typical primary distribution feeder circuit originates at a substation and consists of four separate conductors. Each of the three phase conductors carries current to the loads connected to that phase. Typically each phase may carry a different current and the neutral carries any unbalanced current back to the substation.

Where single phase taps extend from the three phase circuit, the load current in the phase wire is the same magnitude as the current that flows in the neutral.

As a safety consideration, and to provide a voltage reference relative to earth, the neutral is grounded at the substation and at multiple locations which makes it a “multi-grounded” feeder. Individual ground connections are made at utility poles with transformers, voltage regulators, reclosers, switches or lightning arresters and at pad-mounted transformers.

At transformers, the primary and service neutrals are interconnected and grounded. Any other metallic items, including guy wires and communications systems cables, are bonded to the ground conductor, as shown in Figure 1 of Appendix A. The goal is to maintain all equipment at one common voltage reference relative to earth.



TYPICAL UTILITY POLE GROUNDING PRACTICE

GREEN DENOTES GROUNDING



FIGURE 1

DESCRIPTION OF THE CUSTOMER'S GROUNDING SYSTEM

The following discussion has been simplified to present the basic concepts of service grounding within a residential context. The concept applies for both pole and pad-mounted service transformers. A practical guide on this topic is *Soares Book on Grounding, Eighth Edition*, published by the International Association of Electrical Inspectors.

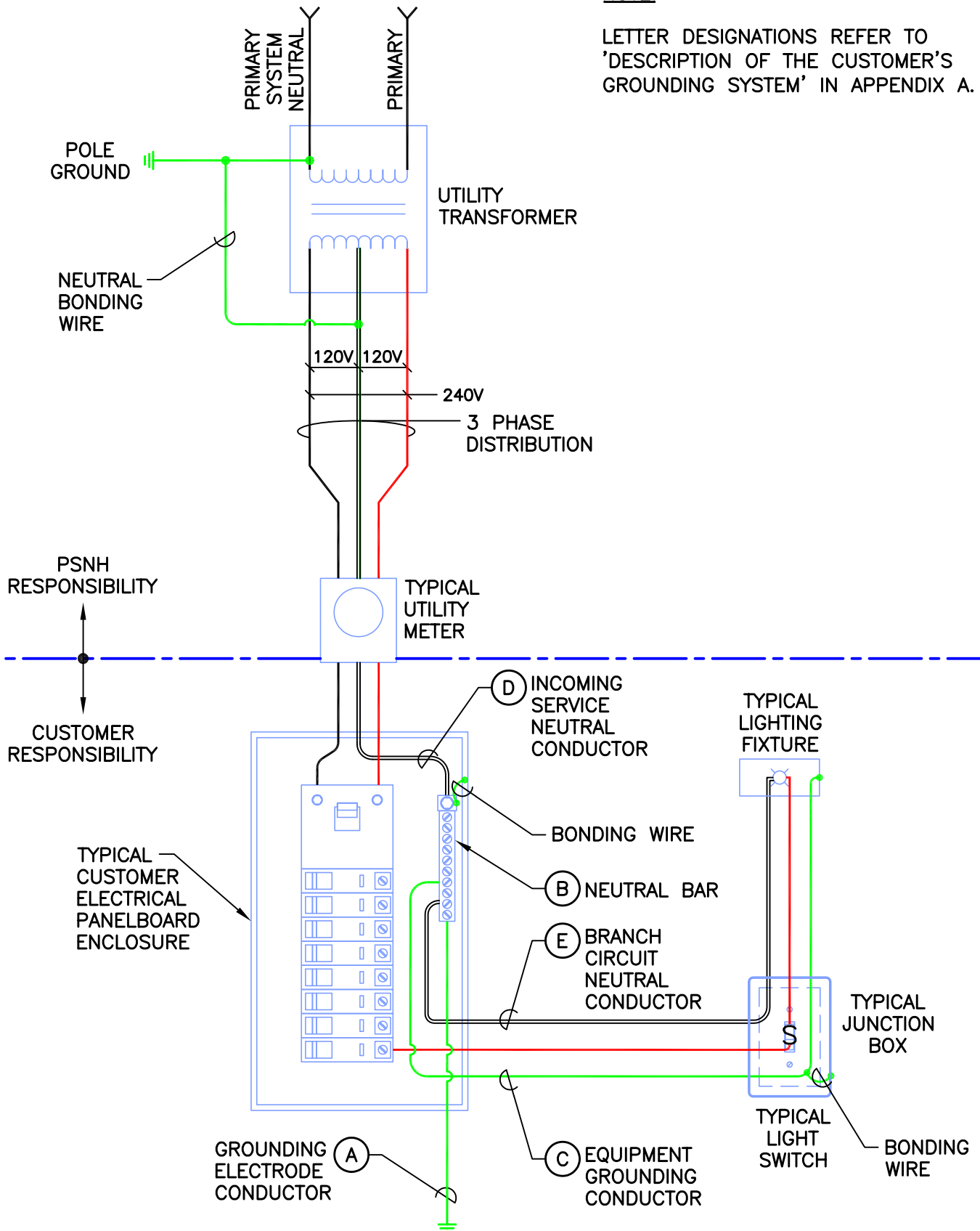
A single phase residential service consists of a neutral wire and two phase wires which extend through the utility meter and terminate in the service equipment, usually a single panelboard containing circuit breakers. The voltage between the two phase wires is 240 volts and between each phase wire and neutral is 120 volts.

Figure 2 of Appendix A shows the general wiring concept at the service equipment and the following letters are keyed to the illustration. The service neutral is connected to a neutral terminal bar. The neutral bar is connected to:

- A The grounding electrode conductor, the wire that extends to the ground electrodes, such as a metallic water pipe, ground rods, or other ground permitted by code. This connection is intended for safety to provide a voltage reference relative to earth and it should not carry any current under normal operating conditions;
- B The neutral bar which is bonded to the panelboard enclosure by a bonding jumper or screw designed for this purpose. Bonding the enclosure places it at earth potential to minimize shock hazards if someone touches the enclosure. The bonding jumper should not carry any current under normal operating conditions;
- C The equipment grounding conductor from each branch circuit which is connected to the neutral bar and serves to bond each junction box, receptacle ground terminal and any other metallic enclosure to the panelboard enclosure and service ground. This conductor serves to bond the grounded panelboard enclosure to other enclosures containing energized wires. It serves as an alternate path for fault current flow to operate the branch circuit breaker. It should not carry any current under normal operating conditions;

NOTE:

LETTER DESIGNATIONS REFER TO
'DESCRIPTION OF THE CUSTOMER'S
GROUNDING SYSTEM' IN APPENDIX A.



TYPICAL CUSTOMER'S GROUNDING SYSTEM

GREEN DENOTES GROUNDING



FIGURE 2

- D The incoming service neutral, from the utility transformer, which is connected to the neutral bar and carries any unbalanced current from the two incoming phase wires;
- E The neutral conductor from each branch circuit which carries the same current as the energized wire from the circuit breaker to the load.

In summary, only the neutral wires carry current. The ground wires carry no current and provide a means to bond all metallic enclosures together and to earth. The neutral and ground conductors are interconnected at only one point at the service equipment and are separate from that point through the building and to any sub-panelboards on the premises.

DESCRIPTION OF UTILITY AND CUSTOMER GROUND INTERCONNECTION

The utility and customer ground systems function together to provide a consistent and electrically interconnected multi-grounded neutral for safety. By maintaining a solidly interconnected system, referenced to earth, safety and reliability are maintained. The utility neutral characteristics are summarized as follows:

- It originates at the source.
- It carries the unbalanced currents of the primary phase wires.
- It is connected to the customer neutrals.
- It is grounded at multiple points along its length and at all customer locations.
- It provides a grounded bonding point for other pole mounted equipment and guy wires.
- The ground connections are not intended to carry current under normal operating conditions.

REALITY CONSIDERATIONS

The above discussion is focused on ideal theoretical conditions and some variation is expected in actual practice. In an ideal world, the neutral carries the unbalanced currents from the phase conductors. What happens if there is an alternate path for current flow from the phase conductor to earth instead of from phase to neutral?

Some situations, such as a dirty or cracked insulator, a tree branch resting on a primary wire, a broken neutral or some other abnormal condition, could provide a leakage path for a small current flow to ground. This current is not large enough to operate a protective device, yet the unbalance of the phase currents does not match the actual neutral current. In such a case, the leakage current would find an alternate path through the earth and return through one or more ground connections. This could result in a measurable current on one or more ground conductors.

Even if the system had no current leakage from phase to ground, there could be some current flow through the ground connections, especially if the ground system resistance was very low. If the resistance of the neutral wire between any two points and the ground resistance between the same two points was equal, approximately half the current would flow through each path. This is purely a function of Ohm's Law as the current flow would divide among any alternate parallel paths and the path of least resistance would have the greatest portion of current flow. Such a situation is inherent in the fact that multiple grounds occur all over the electrical system. In other words, the intent to improve safety by installing multiple grounds has the unintended consequence of providing numerous alternate paths for current to flow.

When we tested sample ground resistance values, we found some ground currents which was not surprising.

CODES AND STANDARDS FOR GROUNDING SYSTEMS

Each utility distribution feeder in Bedford has a multi-grounded neutral conductor, whose purpose is to provide a return path to the source for any current unbalance on the phase conductors. The neutral is intended to carry current under normal operating conditions.

The grounding conductor system is a safety measure to:

- Limit voltages caused by lightning or accidental contact with higher voltage power conductors.
- Provide a voltage reference relative to ground.
- Provide a fault current path for the operation of protective devices.

Specific grounding requirements are listed in the two following sections.

THE NATIONAL ELECTRICAL SAFETY CODE GROUNDING REQUIREMENTS

The National Electrical Safety Code, IEEE C2, 2002 Edition, published by the Institute of Electrical and Electronics Engineers, is the standard used by electric utilities for safeguarding the public from hazards related to overhead and underground power distribution. It contains detailed rules for the construction and operation of power systems up to the customer's meter.

Section 9 contains the requirements for protective grounding of utility systems with key items listed below:

- Rule 096B requires a single point ground to have a resistance of less than 25 ohms, or have a second ground electrode installed.
- Rule 096C requires that the neutral on a multi-grounded system be of sufficient size, grounded at each transformer location and at additional points to provide a minimum of four grounds per mile, not including individual service grounds. The accompanying note indicates that multi-grounded systems depend on the overall effect of multiple grounds rather than the ground resistance of any given electrode. For this reason, no specific ground resistance value is required at each individual electrode.

- Rule 092C3 requires that neutrals, guy wires and messenger wires be bonded and grounded, if all are present on the pole.
- Rule 092D states that there should be no objectionable current flow over the grounding conductor, except during abnormal conditions for the operation of protective devices. If there is objectionable current flow, the grounding system should be modified.
- Rule 314C1 prohibits using the earth as the sole conductor for any part of an electric supply circuit.

NATIONAL ELECTRICAL CODE (NEC) GROUNDING REQUIREMENTS

The National Electrical Code, NFPA-70, 2002 Edition, published by the National Fire Protection Association was adopted by the State of New Hampshire for all electrical installations, as defined by RSA 319-C:2, III. This typically covers electrical services from the utility connection to the customer, including wiring within buildings and on the customer's premises. In particular, Article 230 covers electric services and Article 250 covers grounding systems.

The New Hampshire Electricians Licensing Board, along with the State Electrical Inspectors, provide a web site (<http://www.state.nh.us/electrician/questions.html>) listing the most common electrical deficiencies. One of the items on the 1999 list is the improper installation of ground rods, including the second electrode requirement in the preceding paragraph. It is possible that some customer service grounds may not comply with the NEC.

The NEC is a complex document; however the following key items are applicable to customer service ground connections:

- Article 250.52 lists the types and characteristics of grounding electrodes permitted, including metal underground water pipes with a minimum of 10 feet in direct contact with the earth; grounded metal building frames; concrete encased electrodes; ground

rings; rod and pipe electrodes, plate electrodes and other local underground metal systems. Metallic underground gas system piping is not permitted for grounding.

- Article 250.56 requires that a single rod, plate or pipe ground have a resistance to ground of 25 ohms or less. If this condition is not met, then connection to one additional electrode, as defined in Article 250.52, is required. In actual practice, ground resistance readings are not typically taken and two electrodes are installed to meet this requirement.

PSNH, in its presentation at the March 10, 2004 Bedford Town Council meeting stated that “PSNH requires a customer to install two grounds at the service entrance.”

IEEE GROUNDING REFERENCE DOCUMENTS

The Institute of Electrical and Electronics Engineers (IEEE) publishes specialized technical documents that are used as references in the electrical industry. The publications listed in this section are presented as technical references and are not mandatory requirements.

- *IEEE Standard No. 142-1991, IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems - Green Book, 1991 Edition.* This publication primarily describes grounding systems characteristics and design for industrial and commercial buildings; however the discussion and calculations are generally applicable to any grounding system.
- *IEEE Standard No. 1100-1999. IEEE Recommended Practice for Powering and Grounding Electronic Equipment. - Emerald Book 1999 Edition.* This publication provides a consensus of recommended practices to overcome the conflicting opinions regarding power quality issues relative to electronic equipment. The following are summaries of some key points.

Most users blame the utility source for problems when there may be factors internal to the user's building and equipment that cause power system disturbances. (IEEE 1100, Section 3.2.3)

Some disturbances are “random and are not repeatable or predictable” (IEEE 1100, Section 3.2.6), and may be caused by lightning, storms, vehicle accidents, or human error. Some disturbances are repeatable and can be traced to specific equipment operation such as utility capacitor switching or customer equipment operation such as motors and HVAC equipment cycling on and off.

IEEE 1100, Section 8.5 presents specific and detailed grounding configurations with emphasis on a single point ground and compliance with the NEC.

GROUNDING REQUIREMENTS FOR COMMUNICATIONS SYSTEMS

The *National Electrical Code* also covers grounding requirements for communications, cable TV and receiving antenna installations in Articles 800 through 830. In the simplest concept, each communications service ground wire, up to 20 feet in length, is to be connected to the electric service grounding system. If the communications service entrance is farther away, it should be grounded to a local ground rod, which in turn is bonded back to the electric service grounding system.

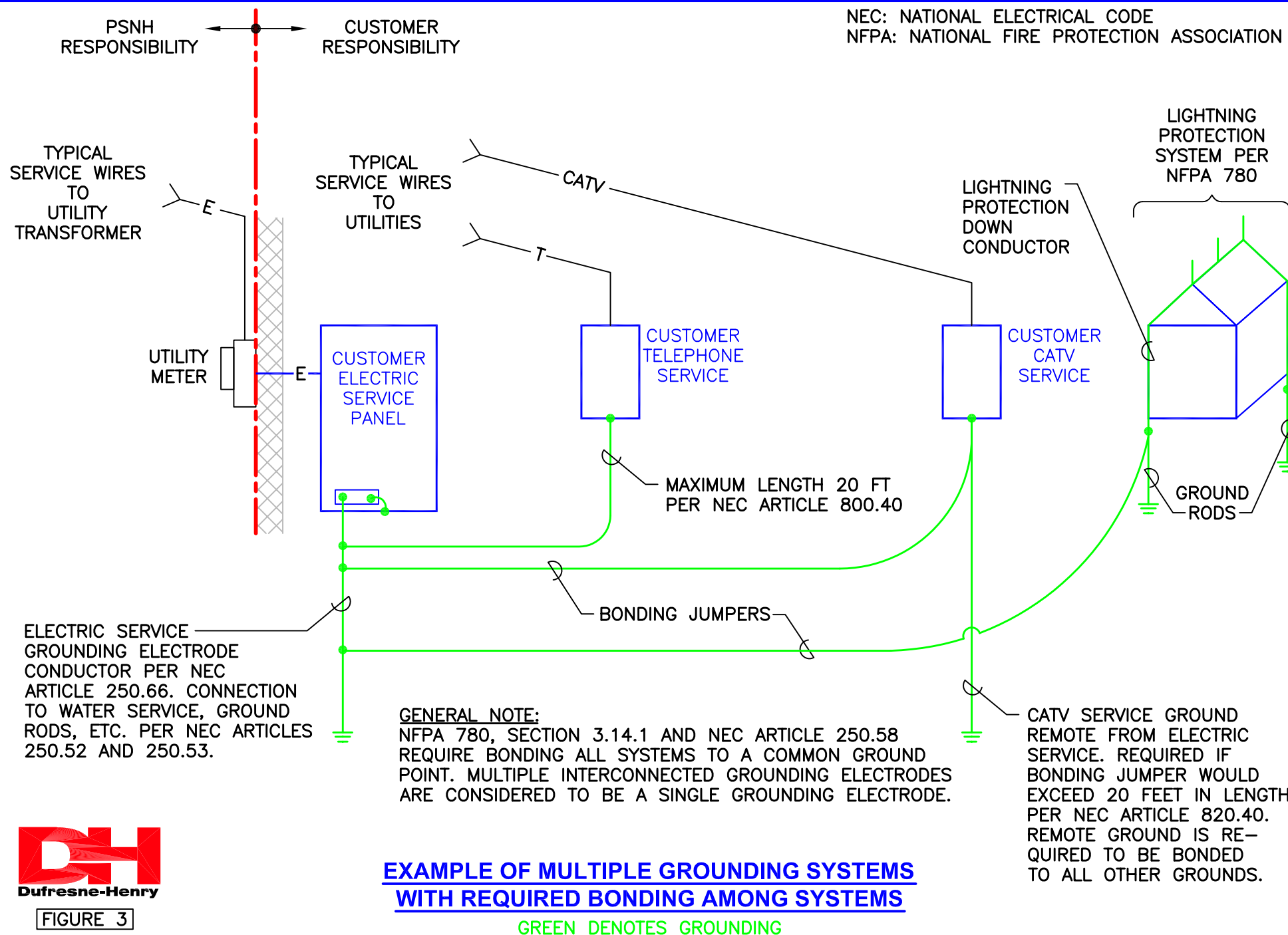
If there is a lightning rod system, it will have a separate ground rod system, but it is also required to be bonded to the electric service ground system, per *NFPA 780, Standard for the Installation of Lightning Protection Systems, 2000 Edition*, paragraph 3.14.1.

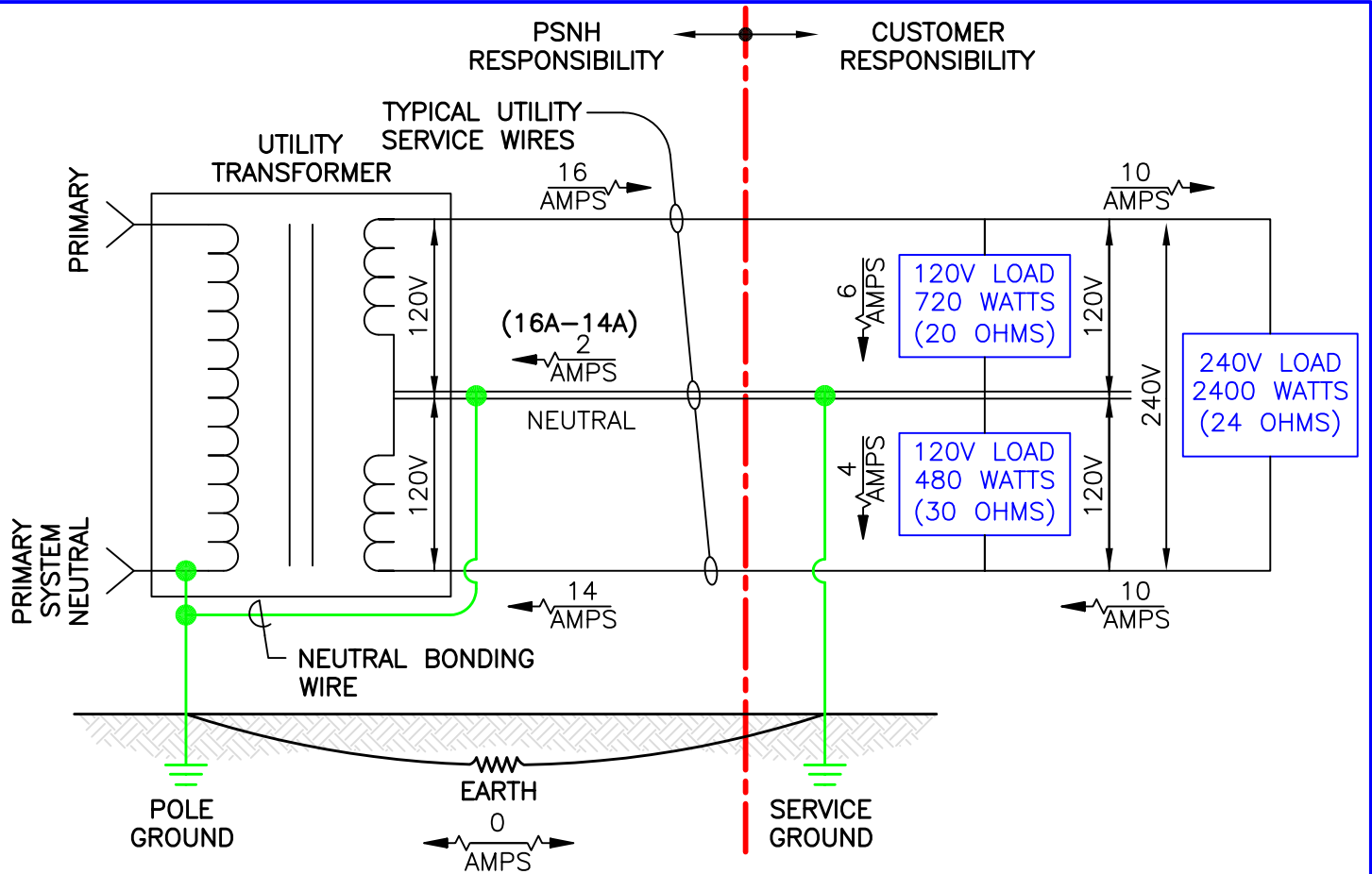
The basic requirement is that there should be a single common ground point for all systems at a building. The NEC is very clear in Article 250.58 that a system of interconnected grounds, bonded together, is considered a single ground. The reason for this is to eliminate voltage differences among different grounding systems at the same location. This is shown on Figure 3 of Appendix A.

DISCUSSION OF A BROKEN NEUTRAL CONNECTION

Figure 4 of Appendix A contains two sketches of a typical residential service with the first showing the correct installation of the neutral and ground conductors. This simplistic example demonstrates one type of problem that could result from a broken or loose neutral

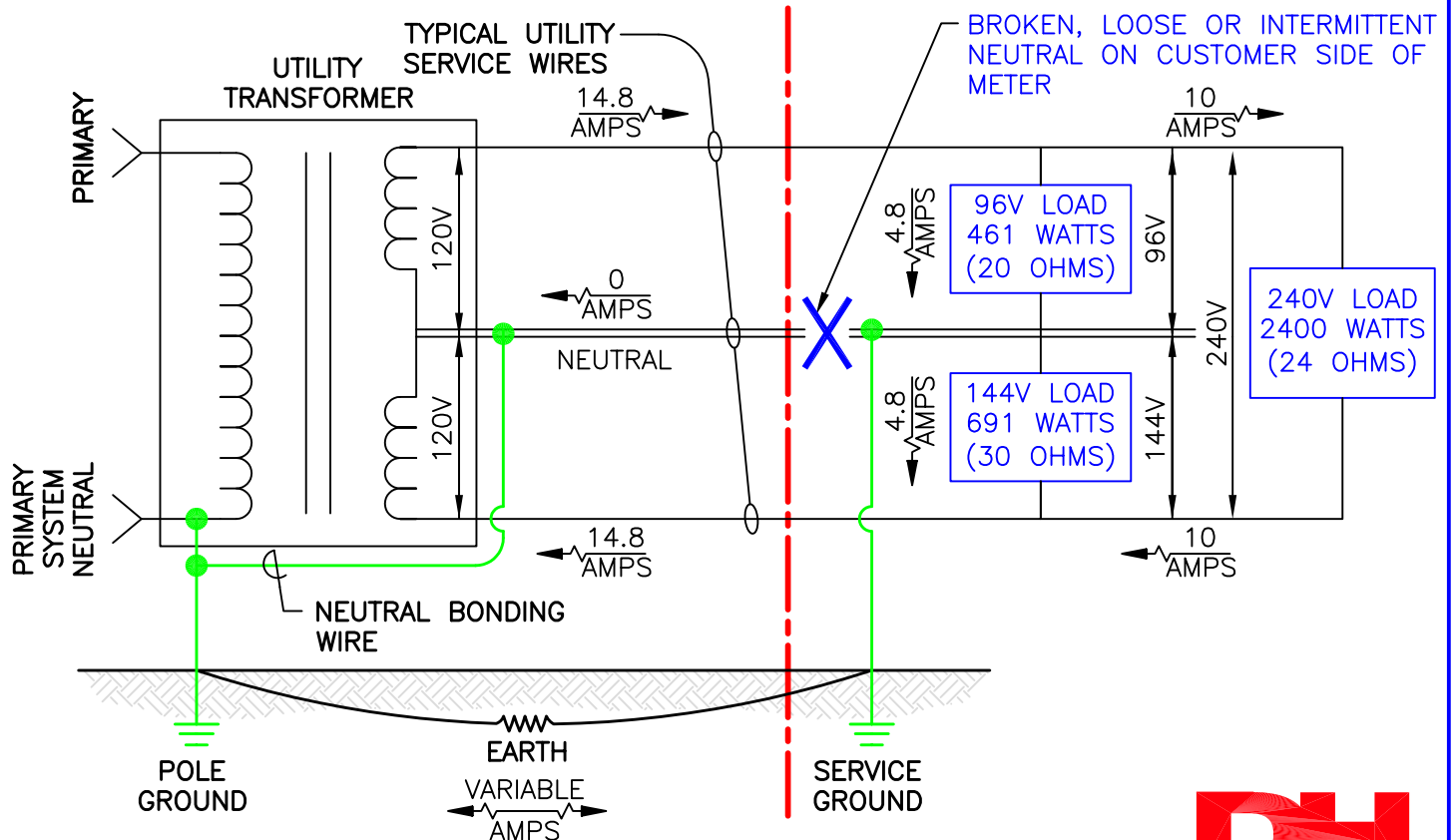
NEC: NATIONAL ELECTRICAL CODE
NFPA: NATIONAL FIRE PROTECTION ASSOCIATION





TYPICAL NORMAL OPERATION

GREEN DENOTES GROUNDING



TYPICAL IMPACT ON CUSTOMER'S VOLTAGE CAUSED BY BROKEN OR LOOSE NEUTRAL

GREEN DENOTES GROUNDING



FIGURE 4

wire at the service panelboard. The numbers were chosen to make the currents on each wire unique and the calculations follow Ohm's law. The power factor is assumed to be 100 percent with totally resistive loads.

The customer panel contains a large 240 volt load and separate representative 120 volt loads from each phase to neutral. The currents are different on each phase wire and the unbalanced current flows on the neutral wire. The ground wire has no current flowing in it. Voltage and current readings taken at the utility transformer are the same as if taken at the service panelboard.

The second sketch is identical, except that the neutral connection to the customer panelboard is broken. Instead of different currents flowing in the 120 volt loads to neutral, the two 120 volt loads are now in series and will divide the 240 volts from phase to phase based on the magnitude of each phase to neutral load. In this case, the neutral is not at zero volts, but floating at some other value that will vary with the size of the 120 volt loads. The only possible connection from the neutral to the source is now through the ground system. The magnitude of ground current that will flow is dependent on a number of factors, including ground resistance, but some current is expected to flow on the ground wire.

Measurement of the voltage and currents at the utility transformer does not indicate that anything is wrong. The current in one phase is equal to that in the other phase so the neutral current would be zero.

Inside the house, the 240 volt load continues to operate unchanged. Only the 120 volt loads are affected by one having a higher than normal voltage and one being lower than normal. If these are lights, some will be brighter and others will be dimmer than normal. If any light is turned on or off, the brightness, and voltage, of the others will also change. These indications might be called a "voltage surge" by some customers because some lamps are brighter than normal. Such a condition is a safety hazard and requires immediate correction.

The point is to illustrate that some problems cannot be measured on the utility side of the meter and must be investigated inside the customer system.

SUMMARY OF GROUNDING REQUIREMENTS

The applicable codes and standards covering grounding were developed as consensus standards and are consistent in concept and application. A properly installed and grounded electrical system is required both for the correct operation of equipment and for personal safety.

APPENDIX B

COMMENTARY ON INCANDESCENT LAMP LIFE

APPENDIX B

COMMENTARY ON INCANDESCENT LAMP LIFE

CONSTRUCTION

An incandescent lamp contains a tungsten filament, basically a thin wire that glows when an electric current flows through it, surrounded by a vacuum or inert gas within a glass bulb. When an electric current flows through the lamp, the filament becomes very hot and produces visible light.

Manufacturers can vary lamp characteristics such as size, shape, color, life, wattage, voltage, and mechanical strength. Unfortunately there are tradeoffs so that as one feature is enhanced, another may suffer as a compromise. Additionally, placing the lamp within a light fixture introduces additional variables including mounting orientation, ambient temperature, ventilation, vibration, and operating voltage.

The lamp life effects are based on information in Chapter 6 of The IESNA Lighting Handbook, Ninth Edition, published by the Illuminating Engineering Society of North America.

LAMP LIFE RATING

Incandescent lamp life ratings are based on manufacture's tests on large groups of lamps and individual variations are expected within a group. Typical lamp mortality curves indicate the following

PERCENT RATED LIFE	APPROXIMATE PERCENTAGE OF LAMPS SURVIVING
60%	95%
80%	80%
100%	50%
120%	20%

Consider a lamp rated for 1,000 hours at 120 volts. Based on the above, it is unrealistic to expect the lamp to operate for 1,000 hours since the manufacturers predict a 50-50 chance that it will last that long. In any group of these lamps, only 50% of lamps will be operational at the rated lifetime in hours.

Typically an incandescent lamp fails, with a flash, at the moment it is turned on. Two factors are responsible – inrush current and a weakened filament.

INRUSH CURRENT

When a cold filament is energized, the initial inrush current is approximately 10 to 20 times greater than normal operating current. Within about one tenth of a second, the filament reaches operating temperature, increases in resistance and the current flow decreases to normal.

FILAMENT DEGRADATION

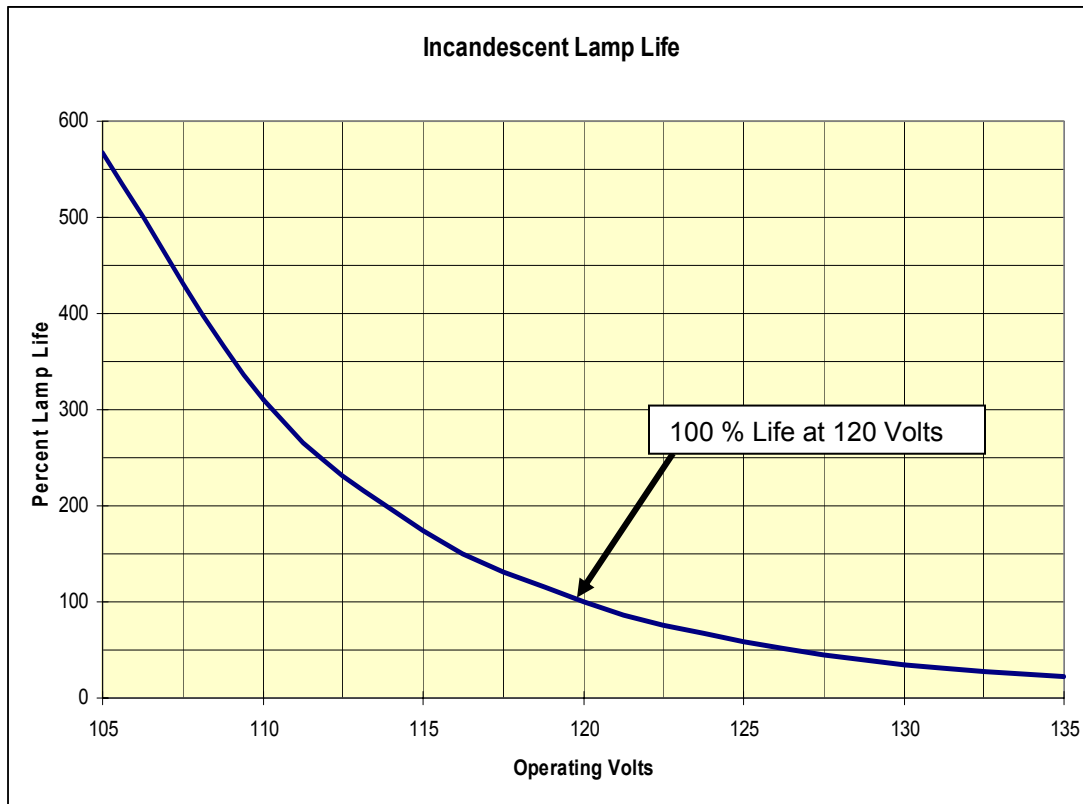
During extended operation, the hot filament surface slowly evaporates at random locations along its length leaving a notched rough surface. The reduced filament diameter at each notch is particularly susceptible to electrical and thermal stresses during the initial current surge and failure ultimately occurs at one of these spots.

VOLTAGE VARIATION

If the lamp operates at a higher than rated voltage, the wattage and current increases and lamp life is reduced. Conversely, if the operating voltage is lower than the lamp rating, the current and wattage are reduced and the life is extended. The theoretical life extension is seldom observed since the lamp usually fails for some other reason, such as vibration during fixture cleaning or other external cause.

The theoretical effect of voltage on lamp life is based on constant voltage laboratory conditions; however in practice the operating voltage may be constantly changing in response to variable load changes by all customers on a utility system. Lamp life variations are calculated by the ratio of rated voltage to operating voltage raised to the 13th power. The

information illustrated in the following graph is intended to show the relationship between lamp life and voltage and is most applicable within +/- 10% of nominal voltage.



SUGGESTIONS

Some possible options to overcome reported short incandescent lamp life can be evaluated by individual customers in an attempt to resolve these issues. This listing is not necessarily comprehensive and is presented in the form of suggestions which may, or may not, be applicable in any specific situation.

- Use 130 volt long life lamps instead of 120 volt lamps. This approach is applicable where the operating voltage is found to be higher than 120 volts.
- Use rough service lamps where the lamps are subject to vibration, as the filament structure is more substantial than normal lamps.
- Check lamp sockets for loose wiring connections.

- Check the center lamp contact to insure that is making firm contact with the lamp. Poor connections will create heat that can shorten lamp life.
- Try lamps by different manufacturers as lamp construction varies. Lamps from the major manufacturers have been reported to last longer than those from other sources.
- Consider replacing standard incandescent lamps with compact fluorescent lamps.
- Decorative lamps are typically low wattage and constructed with fine filaments which can be prone to failure more frequently than typical incandescent lamps. Consider operating these fixtures through a dimmer switch at a setting somewhat less than full brightness. If the lamp is started by turning up the dimmer from zero brightness, the inrush current effect can be minimized. The use of a dimmer in this manner on any incandescent lamp may help lengthen lamp life. One caution however; higher quality dimmers are reported to perform better than the less expensive types which may aggravate flicker at partial brightness settings.

					Item Numbers from Power Survey Form. Item #2 – Failures – Expanded to List Specific Equipment Failures																																			
Circuit	Index No.	Source	Address	Date	1. Blinking lights	2. Failed Well Pump Sump Pump	TV	Cordless Phone	Alarm Clock	Answering Machine	Microwave	VCR	Refrigerator	HVAC	Computer	Radio/Stereo	Trash Compactor	Range/Oven	Washer	Dryer	Dishwasher	Hot Water Heater	Water Softener	DVD Player	Video Game	Pool Pump	Light fixtures	Toaster	Coffee Maker	Garage Door Opener	Hair Dryer	Electric Blankets	Radon System		3. Light Bulb	4. High Bills	5. Flickering Lights	Index No.	6. Other Comments	
3W1	1	E1	Barrington Drive	03/05/2003																																	1	Upgrade facilities to mitigate flicker, submitted 'hot spot' tree trimming request		
3W1	2	E1	Gage Road	10/04/2002																																	2	Removed tree limbs on Liberty Hill to eliminate momentaries, within NHPUC limits		
3W1	3	E1	Harrod Lane	07/03/2002																																	3	Found bad secondary connections in handhole, repaired and checked		
3W1	4	PS	Horizon Dr.	02/07/2003	x	x											x																				4	Voltage variation improved, spikes noted		
3W1	5	PS	Liberty Hill Rd.	03/18/2003	x	x	x	x		x	x																								x	x	5	Lights dim when major appliance starts		
3W1	6	E1	Oak Drive	06/12/2003																																	6	Recorded one minor voltage sag system event, no action, within NHPUC limits		
3W1	7	EM	Meadowcrest Dr.	03/28/2003		x							x							x																	7	E-mail to Power Survey Bedford. One year old Dishwasher pump failed		
3W1	8	PS	Stebbins Pond Dr.	03/04/2003	x	3	2																														8	No comments		
3W1	9	SPS	Stebbins Pond Dr.	05/28/2003		2	1																														9	30 minute monitoring		
3W1	10	E1	Teaberry Lane	09/29/2003																																		10	PSNH found loosed load side connection in meter box	
3W1	11	E1	Tirrell Rd.	07/15/1999																																		11	Upgraded existing 25 KVA padmount transformer to 100 KVA	
3W1	12	E1	Green Meadow La.	07/15/1999																																		12	Regulator to be installed on circuit feeding this customer	
3W2	101	E1	Amherst Rd.	04/19/2001																																		101	Move transformer closer to customer (exist. 440 ft service), will upgrade & recheck	
3W2	101	E1	Amherst Rd.	06/07/2001																																		101	Recheck done after service upgrade	
3W2	102	E1	Birchwood Cir.	09/08/1999	x								x																									102	Reviewed voltage check w/ customer, no repeat of problem, with NHPUC limits	
3W2	102	EM	Birchwood Cir.	02/12/2003									x																										102	Equipment dims, slows then returns
3W2	103	E1/EM	Birchwood Cir.	03/24/2003																																			103	Recorded one minor voltage sag system event, no action, within NHPUC limits
3W2	104	PS	Camelot Dr.	02/13/2003	x			x	x	x	x					x																							104	PSNH did not find issues
3W2	105	E1	Camelot Dr.	04/04/2003																																				

CA	NHPUC Consumer Affairs Survey
E1	PSNH E1 Form
EM	E-Mail
LTR	Letter
NOTE	Note
PS	Power Survey By Residence
SPS	State Initiated Power Survey



SOURCE: 360 LINE
AT 34.5 KV
360X5 TAPS OFF
(1 PHASE)

NEW
BOSTON

AMHERST

MERRIMACK

GOFFSTOWN

34.5 KV TRANSMISSION
LINE PATH CIRCUITS
321 AND 322

SOURCE: 322 LINE AT 34.5 KV
322X10 TAPS OFF
(3 PHASE)

SOURCE: 322 LINE AT 34.5 KV
322X12 TAPS OFF
(3 PHASE)

SOURCE: 322 LINE AT 34.5 KV (SINCE 1998)
FOR MEETINGHOUSE ROAD SUBSTATION
(3 PHASE)

34.5 KV TRANSMISSION
LINE PATH CIRCUITS
321 AND 322

MANCHESTER

34.5 KV TRANSMISSION
LINE PATH CIRCUITS
321 AND 322

CIRCUIT LEGEND	
	CIRCUIT 3W1
	CIRCUIT 3W2
	CIRCUIT 322X10
	CIRCUIT 322X12
	CIRCUIT 360X5

EQUIPMENT LEGEND	
	CAPACITOR BANK AND NUMBER. REFER TO 'CAPACITOR BANK SCHEDULE'.
	RECLOSER AND NUMBER. NUMBERS 1, 2 AND/OR 3 DENOTE PHASE. NUMBER IN PARENTHESES () DENOTES QUANTITY. REFER TO '5 YEAR RECLOSER ACTIVITY SCHEDULE'.
	VOLTAGE REGULATOR AND NUMBER. REFER TO 'VOLTAGE REGULATOR SCHEDULE'.
	DIRECTION OF FLOW
	SUBSTATION
	TRANSFORMER: 'SDT' DENOTES STEP-DOWN TRANSFORMER 'SUT' DENOTES STEP-UP TRANSFORMER
	N.O. NORMALLY OPEN TIE POINT
	LOCATION OF CUSTOMER CONCERN REFER TO 'CUSTOMER CONCERN SCHEDULE'
	DENOTES LINE PHASE OR PHASES
	CIRCUIT UPGRADE/TRANSFER. REFER TO 'CIRCUIT UPGRADE/TRANSFER SCHEDULE'.

NOTES:

1. MEETINGHOUSE ROAD SUBSTATION CIRCUITS 3W1 AND 3W2 OPERATING AT 12.47KV: -FED BY THE 322 LINE OPERATING AT 34.5 KV.
2. CIRCUITS 322X10 AND 322X12: -FED BY THE 322 LINE OPERATING AT 34.5 KV.
3. CIRCUIT 360X5-FED BY THE 360 LINE OPERATING AT 34.5 KV. -THIS LINE ORIGINATES AT THE GREGG SUBSTATION IN NEW BOSTON.
4. OTHER CIRCUITS SHOWN FOR INFORMATION ONLY.

TOWN OF BEDFORD
ELECTRICAL DISTRIBUTION CIRCUIT MAP
NEW HAMPSHIRE PUBLIC UTILITY COMMISSION

DOCKET NO. DE 03-113



FIGURE 2.2A
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5 YEAR RECLOSER ACTIVITY SCHEDULE																																							
RECLOSER NUMBER	CIRCUIT NUMBER	POLE NUMBER	STREET NAME	1999							2000							2001							2002							2003							COMMENT
				A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	D	E	F	A	B	C	Outages	D	E	F					
①	3W1	6/11 (2)	BACK RIVER ROAD	2	0	0	2	207	414		10	0	4	6	231	1,386	3	0	0	3	231	693		9	0	0	9	231	2,079	0	0	0	0	0	231	0			
②	3W1	6/11 (3)	BACK RIVER ROAD	5	0	0	5	201	1,005		11	0	8	3	260	780	18	0	0	18	260	4,680		17	0	0	17	260	4,420	0	0	0	0	0	260	0			
③	3W1	6/11 (1)	BACK RIVER ROAD	3	0	0	3	195	585		7	0	4	3	338	1,014	22	0	4	18	338	6,084		8	0	0	8	338	2,704	23	0	2	1	21	338	7,098			
④	3W1	6/69 (2)	BACK RIVER ROAD	1	0	0	1	146	146		5	0	4	1	146	146	4	0	4	0	146	0		6	0	0	6	146	876	7	0	4	1	3	146	438			
⑤	3W1	1/76 (3)	D W HIGHWAY	2	0	0	2	26	52		4	0	4	0	26	0	3	0	0	3	25	75		1	0	0	1	25	25	0	0	0	0	0	25	0			
⑥	3W1	1/76 (2)	D W HIGHWAY	1	0	0	1	28	28		5	0	4	1	28	28	3	0	0	3	25	75		0	0	0	0	25	0	4	0	4	1	0	25	0			
⑦	3W1	1/76 (1)	D W HIGHWAY	0	0	0	0	24	0		1	0	0	1	24	24	0	0	0	0	23	0		0	0	0	0	23	0	0	0	0	0	0	23	0			
⑧	3W1	Meetinghouse S/S	MEETINGHOUSE ROAD	4	0	3	1	1,041	1,041		0	0	0	0	1,082	0	9	6	0	3	1,105	3,315		3	0	0	3	1,235	3,705	5	5	0	0	0	1,235	0			
⑨	3W1	6/87Y (1)	REEDS FERRY BK ROAD	3	0	0	3	158	474		4	0	3	1	158	158	18	0	3	15	158	2,370		2	0	0	2	158	316	6	0	0	0	6	158	948			
⑩	3W2	10/52 (3)	LIBERTY HILL ROAD	12	0	0	12	253	3,036		6	0	0	6	253	1,518	3	0	0	3	253	759		0	0	0	0	253	0	4	0	0	0	4	253	1,012			
⑪	3W2	Meetinghouse S/S	MEETINGHOUSE ROAD	1	0	1	0	1,392	0		40	40	0	0	1,369	0	15	13	2	0	1,376	0		1	0	0	1	1,376	1,376	23	21	2	1	0	1,376	0			
⑫	3W2	842/39 (1)	N AMHERST ROAD	15	0	12	3	118	354		6	0	0	6	125	750	10	0	0	10	125	1,250		17	0	16	1	125	125	4	0	4	1	1	125	125			
⑬	3W2	842/39 (3)	N AMHERST ROAD	17	0	8	9	140	1,260		1	0	0	1	128	128	2	0	0	2	128	256		16	0	8	8	128	1,024	4	0	3	1	1	128	128			
⑭	3W2	842/39 (2)	N AMHERST ROAD	31	0	12	19	217	4,123		3	0	0	3	183	549	9	0	0	9	183	1,647		34	0	20	14	183	2,562	3	0	1	1 *	2	183	366	* Manual Outage for Maintenance		
⑮	322X10	11/270Y	McALLISTER ROAD	0	0	0	0	152	0		3	0	0	3	108	324	8	0	4	4	108	432		4	0	0	4	108	432	5	0	0	0	5	108	540			
⑯	322X10	2/81	WALLACE ROAD	6	0	0	6	140	840		10	0	0	10	140	1,400	5	0	0	5	140	700		3	0	3	0	140	0	15	0	4	1	11	140	1,540			
⑰	322X10	337/10	BOXWOOD ROAD	3	0	0	3	91	273		1	0	0	1	91	91	2	0	0	2	91	182		0	0	0	0	91	0	0	0	0	0	0	91	0			
⑱	322X10	25/191Y	NEW BOSTON ROAD	0	0	0	0	108	0		6	0	2	4	144	576	0	0	0	0	185	0		0	0	0	0	185	0	0	0	0	0	0	185	0			
⑲	322X12	65 1/2	BOYNTON STREET	2	0	0	2	1,723	3,446		0	0	0	0	1,611	0	3	0	0	3	1,611	4,833		16	6	9	1	1,685	1,685	8	0	3	1	5	1,685	8,425			
⑳	322X12	220/17 (1)	NASHUA ROAD	25	0	4	21	86	1,806		6	0	4	2	86	172	28	0	0	28	86	2,408		0	0	0	0	86	0	6	0	4	1	2	86	172			
㉑	360X5	360/105 (3)	NEW BOSTON ROAD														3	0	0	3	509	1,527		9	0	9	0	544	0	0	0	0	0	544	0	INSTALLED IN 2001			
SCHEDULE KEY: A: TOTAL COUNTS. B: TEST COUNTS. C: LOCKOUT OPERATIONS (SUSTAINED OUTAGE). D: NET OPERATIONS (MOMENTARY OPERATION OF DEVICE). E: CUSTOMERS/OPERATION (CUSTOMERS ON DEVICE). F: MOMENTARY INTERRUPTIONS (TOTAL NUMBER OF CUSTOMERS AFFECTED BY A MOMENTARY OPERATION). 2003 OUTAGES: ACTUAL NUMBER OF SUSTAINED OUTAGES IN 2003 ONLY.																																							

CAPACITOR BANK SCHEDULE (POLE MOUNTED, TYPICAL)										
CAPACITOR NO.	CIRCUIT	STREET NAME	POLE NUMBER	VOLTAGE	NO. OF PHASES	KVAR	CONTROL TYPE	TIME ON	TIME OFF	COMMENTS
①	321	321 LINE	321/57	34500	3	2400	TIME	9:00 AM	9:30 PM	
②	321	321 LINE	321/77	34500	3	2400	TIME / VOLT	7:00 AM / 116.0 V	9:00 PM / 125.0 V	Except Saturday and Sunday
⑩	321	321 LINE	321/94	34500	3	2400	TIME / VOLT	7:15 AM / 116.0 V	9:15 PM / 125.0 V	Except Saturday and Sunday
③	322	322 LINE	322/78	34500	3	2400	TIME / VOLT	7:10 AM / 120.0 V	9:10 PM / 124.0 V	Except Saturday and Sunday
⑬	321X9	HOLBROOK RD.	239/199	7200	1	50	FIXED	N/A	N/A	
④	322X10	NEW BOSTON RD.	25/93	34500	3	600	TEMP / VOLT	86.9 DEG / 116.0 V	82.2 DEG / 125.0	
⑤	322X10	McALLISTER RD.	11/273	7200	1	150	FIXED	N/A	N/A	OFF LINE
⑥	322X12	ROUTE 101	5W/15	34500	3	1200	TIME	6:00 AM	10:00 PM	Except Saturday and Sunday
⑦	322X12	ROUTE 101	5W/80.5	34500	3	1200	TEMP / VOLT	86.9 DEG / 116.4 V	82.2 DEG / 125.0 V	
⑧	360X5	JOPPA HILL RD.	1083/79	7200	1	100	FIXED	N/A	N/A	
⑨	3W1	SOUTH RIVER RD.	1/69	12470	3	600	TIME / VOLT	6:00 AM / 116.4 V	11:00 PM / 125.0 V	
⑪	3W1	BACK RIVER RD.	6/46	12470	1	150	FIXED	N/A	N/A	
⑫	3W1	REEDS FERRY BACK RD.	6/104	7200	1	50	FIXED	N/A	N/A	
⑭	3W2	MEETINGHOUSE RD.	9/52	12470	3	300	TIME	6:30 AM	11:00 PM	Except Sunday
⑮	3W2	MEETINGHOUSE RD.	9/29	12470	3	300	TIME	8:00 AM	11:00 PM	Except Sunday
⑯	3W2	N. AMHERST RD.	842/16	12470	3	300	TIME / VOLT	7:00 AM / 116.4 V	9:00 PM / 125.0 V	Except Sunday
⑰	3W2	LIBERTY HILL RD.	10/72	7200	1	100	FIXED	N/A	N/A	

PSNH ONGOING TREE TRIMMING SCHEDULE					
CIRCUIT NUMBER	TOTAL LENGTH IN MILES	LAST TRIMMING CYCLE	TOTAL MILES TRIMMED	NEXT TRIMMING SCHEDULED	TOTAL MILES SCHEDULED
3W1	28.05	1999	27.46	2004	28.05
3W2	52.05	1998	51.93	2004	52.05
322X10	11.94	2000	11.87	2004	11.94
322X12	85.53	2002	85.53	2008	85.93
360X5	14.1	2002	14.1	2008	14.1
OTHER CIRCUITS					
12X6	2.28	2000	2.28	2004	2.28
360X	5.6	2003	5.62	2007	5.62
323X5	48.4	2001	48.04	2006	48.4
321X1	4.09	2000	4.09	2004	4.09
321X10	3.5	2000	3.5	2004	3.5

CIRCUIT UPGRADE/TRANSFER SCHEDULE		
SYMBOL NUMBER	CICUIT NUMBER	UPGRADE/TRANSFER DISCRPTION
①	3W1	RECENTLY TRANSFERRED OFF CKT 3W1
⑪	3W2	RECENTLY TRANSFERRED OFF CKT 3W2 TO CKT 322X12
⑫	3W2	NEW SPACER CABLE
㉑	322X10	RECENTLY TRANSFERRED OFF CKT 360X5
㉒	322X10	NEW 3 PHASE TREE WIRE
㉓	322X10	RECENTLY REMOVE FROM FIELD AND CONVERTED TO 34.5 KV
㉔	322X10	RECLOSER HAS BEEN REMOVED
㉕	322X10	NEW SPACER CABLE
㉙	322X12	RECENTLY TRANSFERRED FROM CKT 3W2
㉚	322X12	NEW LINE WITH NEW TREE WIRE

PSNH MONITORING LOCATIONS SCHEDULE AS OF MAY 2004						
SYMBOL NUMBER	CIRCUIT NUMBER	POLE/PAD NUMBER	LOCATION/ STREET NAME	DEVICE NUMBER	MANUFACTURER MODEL NUMBER	ENGINEER
1	3W1	1/64-T1	169 RIVER ROAD	S/N 15516	NONE LISTED	RMM
2	321X1	193/4-1-T1	HOME GOODS	S/N 15515	NONE LISTED	RMM
3	3197X	NO DATA	SEGWAY	S/N 15519	NONE LISTED	RMM
4	322X12	NO DATA	BEDFORD VILLAGE INN	S/N 15517	NONE LISTED	RMM
5	322X10	NO DATA	RIDDLE BROOK SCHOOL	S/N 15518	NONE LISTED	RMM
6	3W2	NO DATA	McKELVIE SCHOOL	S/N 55011	NONE LISTED	RMM
7	3W1	306/32	SMITH ROAD	5090	TELEMETRIC TVM1	MDM
8	360	25/268	DONALD STREET	5091	TELEMETRIC TVM1	MDM
9	322X10	314/4	STONEHENGE ROAD	5092	TELEMETRIC TVM1	MDM
10	322X10	314/4	STONEHENGE ROAD	5796	TELEMETRIC TVM1	MDM
11	322X12	3-Aug	JENKINS ROAD	5093	TELEMETRIC TVM1	MDM
12	322X12	3-Aug	JENKINS ROAD	5674	TELEMETRIC TVM1	MDM
13	3W2	842/25	N. AMHERST ROAD	5688	TELEMETRIC TVM3	MDM

- NOTES:
- TELEMETRIC DEVICES DO NOT PROVIDE CONTINUOUS REPORTING, JUST EXCEPTION REPORTS, AND MIN/MAX SINCE LAST REQUEST.
 - DUPLICATE METERS ARE IN PLACE TO DETERMINE WHETHER UNITS ARE OPERATING PROPERLY AND CONSISTENTLY.
 - NUMBER 7 THROUGH 13 ARE NEW METER LOCATIONS 'NOT YET USED'.
 - DATA REPRESENTS LOCATIONS OF RECORDING DEVICES (METERS) AS OF 05-06-2004.
 - APPROXIMATE LOCATIONS ARE SHOWN ON THE ELECTRICAL DISTRIBUTION CIRCUIT MAP (FIGURE 2.2A).

CIRCUIT/CONDUCTOR SCHEDULE					
CIRCUIT NUMBER	STREET NAME	NUMBER OF PHASES	STREET PHASE	PRIMARY WIRE SIZE AND TYPE	COMMENT
3W1	MEETINGHOUSE ROAD	3		4/0 BARE	
3W1	BACK RIVER ROAD	3		#2 CU BARE	
3W1	COUNTY ROAD (WEST)	1	2	1/0 BARE	ENDS AT MEADOW CREST
3W1	COUNTY ROAD (EAST)	1	3	#2 CU BARE	
3W1	TIRRELL ROAD	3		(2) 1/0 & 2/0 BARE	
3W1	MEADOW CREST DRIVE	1	2	#2 BARE	
3W1	BACK RIVER ROAD	1	1	#2 BARE	SOUTH OF MEADOW CREST
3W1	SMITH ROAD	1	1	1/0 BARE	
3W2	MEETINGHOUSE ROAD	3		4/0 SPACER	
3W2	LIBERTY HILL	3		1/0 SPACER	
3W2	MINISTERIAL ROAD	1	3	1/0 BARE	
3W2	NORTH AMHERST ROAD	3		1/0 BARE	
3W2	CAMPBELL ROAD	3		1/0 SPACER (NEW)	
3W2	CAMPBELL ROAD	1	1	1/0 BARE	
3W2	NORTH AMHERST ROAD	2	1, 2	1/0 BARE	
3W2	PERRY ROAD	1	1	#2 BARE	
322X10	DONALD STREET EXT.	3		477 BARE	
322X10	(NEW BOSTON ROAD)	3		1/0 BARE (E. OF RT 114)	
322X10	TERRILL HILL ROAD	1	3	NOT SHOWN	
322X10	McALLISTER ROAD (NORTH)	1	1	#2 BARE	
322X10	McALLISTER ROAD (SOUTH)	1	1	#2 BARE	
322X10	WALLACE ROAD (NORTH)	1	3	#2 BARE	
322X10	WALLACE ROAD (SOUTH)	1	2	1/0 BARE	
322X12	RT. 101	3		477 BARE	
322X12	PILGRIM DRIVE	1	2	#2 BARE	
322X12	PINECREST DRIVE	1	3	#2 BARE	
322X12	NASHUA ROAD	3		1/0 BARE	
322X12	WALLACE ROAD	1	1	#2 BARE	
322X12	RT. 101	3		477 BARE	
322X12	HARDY ROAD	1	2	#2 BARE	
322X12	JENKINS ROAD	1	1	#2 BARE	
322X12	RT. 101	3		477 BARE	
322X12	BEAVER LANE	1	1	1/0 BARE	
322X12	GAGE GIRLS ROAD	1	3	#2 BARE	
322X12	STOWELL ROAD	1	1	1/0 BARE	
322X12	JOPPA HILL ROAD	1	1	1/0 BARE	
360X5	NEW BOSTON ROAD	1	3	#2 BARE	
360X5	PULPIT ROAD (NORTH)	1	3	#2 BARE	
360X5	PULPIT ROAD (SOUTH)	1	3	#4 BARE	
360X5	KING ROAD	1	3	1/0 BARE	
360X5	JOPPA HILL ROAD (NORTH)	1	3	#2 BARE	
360X5	JOPPA HILL ROAD (SOUTH)	1	3	#2 BARE	
NOTE: 'BARE' INDICATES WIRE IS EXPOSED/UNCOVERED.					